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TENSILE PROPERTIES OF BERYLLIUM AT HIGH STRAIN RATES AND TEMPERATURES

by

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TECHNICAL REPORT AFML-TR-69-273

OCTOBER, 1969

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FOREWORD

This final technical report was prepared by the Materials and Structures Laboratory of Manufacturing Development, General Motors Corporation under Contract F33615-69-C-1496, Project No. 7381, "Materials Applications" and Project No. 7351, "Metallic Materials".

This report covers work conducted from April, 1969 to September, 1969. The manuscript was released by the authors in September, 1969 for publication as a technical report. The contract was monitored jointly by Mr. C. L. Harmsworth/MAAE, and Dr. T. Nicholas and Captain J. Blass/MAMD.

The authors wish to acknowledge Dr. David Holt, Massachusetts Institute of Technology, and Dr. Marvin Herman, Allison Division, General Motors Corporation, for their competent technical assistance during this study. Recognition is also given Mr. Hoyle Simmons for instrumentation of the mechanical tests, Mr. Charles Whitchurch for the metallography, and Mr. Sidney Green, Head of the Materials and Structures Laboratory for his review and comments on this work.

This technical report has been reviewed and is approved.

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ABSTRACT

Dynamic mechanical properties were determined for three grades of beryllium: N-50, S-200E and S-200 cross rolled sheet. Results are reported for uniaxial stress tension tests at strain rates between 10^{-3} and 10^{3} sec^{-1} at temperatures from 72 to 700°F. This data and that from a previous report[1] are compared for the affect of three material parameters (beryllium oxide content, grain size, and texture) on the mechanical properties. The change of strain rate sensitivity with changes in these material parameters is discussed.

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SECTION I

INTRODUCTION

The need for materials in applications requiring a high strength to weight ratio and high modulus has resulted in increased use of beryllium. However, knowledge of the effect of three important material parameters, oxide concentration, grain size and texture (primarily caused by fabrication history) on the mechanical properties at high strain rates and elevated temperature is quite limited. In an effort to compare these effects, this report presents the results of uniaxial tension tests on three grades of beryllium at 72, 300, 500 and 700°F over a wide range of strain rates. In addition, data from Reference 1, a previous report, is discussed and compared to the data obtained in the current effort. This permits comparison of six beryllium grades tested in one laboratory using similar testing techniques.

These six materials may be divided into three groups, ideally each having two similar material parameters and one significantly different; therefore, each group provides data necessary to isolate the effect of one material parameter. The influence of oxide concentration on the tensile properties, flow stress and ductility, can be gaged by comparing the data from three hot pressed beryllium grades having different oxide concentrations (0.9, 2.0 and 4.0-7.0% BeO) but somewhat similar grain size and fabrication history. A hot pressed block material and a cross rolled sheet made from material of similar oxide level are compared to measure the effect of texture. Two hot pressed block materials having nearly equal impurity levels are compared to observe differences resulting from grain size. The materials were all tested over a wide range

of strain rates and in addition to comparison of flow stress and ductility, the sensitivity of the flow stress and ductility to strain rate is compared. Appendixes are provided including the stress-strain curves of the materials at all the different testing conditions.

SECTION II

MATERIAL

The materials selected for the current study include two hot pressed block materials, N-50 and S-200E, and a highly textured cross rolled sheet of S-200 material, all obtained from Brush Beryllium Corporation. All test specimens of N-50 block and S-200 sheet were removed from a small piece of the respective material to minimize material scatter, but specimens from two different blocks of S-200E were tested due to abnormal results obtained using the first block. A limited description of the materials in Reference 1 (S-200D hot pressed block, I-400 hot pressed block and high purity ingot sheet) is given for easy comparison with those materials included in the present effort.

The nominal chemical composition and grain size for all materials are given in Table I with quoted grain size determined using a standard intercept procedure[2].

TABLE I

NOMINAL CHEMICAL COMPOSITION

Grade	Be	BeO	C	Fe	Al	Si	Mg	Cu	Other Impurities Each Less Than	Grain Size
N-50	99.0 (Min)	0.9 (Max)	0.10 (Max)	0.075 (Max)	0.075 (Max)	0.06 (Max)	0.03 (Max)	0.015 (Max)	.015	40μ
S-200 Be Sheet	98.0 (Min)	2.0 (Max)	0.15 (Max)	0.18 (Max)	0.16 (Max)	0.08 (Max)	0.08 (Max)	-	0.04	13μ
S-200E Block #1	98.0 (Min)	2.0 (Max)	0.15 (Max)	0.18 (Max)	0.16 (Max)	0.08 (Max)	0.08 (Max)	-		20μ
S-200E Block #2 (Actual composition)	98.8	0.98	0.09	0.13	0.09	0.05	0.02	-	0.04	18μ
I-400*	93.0 (Min)	4.0-7.0	0.15 (Max)	0.18 (Max)	0.16 (Max)	0.08 (Max)	0.08 (Max)	-	0.04	8μ
S-200D*	98.0 (Min)	2.0 (Max)	0.15 (Max)	0.18 (Max)	0.16 (Max)	0.08 (Max)	0.08 (Max)	-	0.04	35μ
Ingot Sheet* (Actual composition)	99.4	0.03	0.166	0.145	0.076	0.05	0.01	0.009	0.025	100-300μ

* Reference 1

Although the S-200D and S-200E have the same specified impurity limits, the difference in powder origins could make the actual impurity levels and other physical properties different. The type D material is made from a blend of virgin, prime virgin and recycled powders, while the type E materials are made from virgin and prime virgin powder only. The recycled powder is made by the attrition of beryllium chips returned from machining operations, the virgin powder from vacuum melted ingots of previously hot pressed material, and the prime virgin powder from vacuum melted ingots of material having no previous hot pressing history. The powder made from vacuum melted ingots produces material with more uniform particle size and impurity levels. The difference in grain size is due to the use of a -325 mesh screen for the E material versus a -200 mesh screen for the D material. Figure 1a, b and c are representative photomicrographs depicting the grain structure of the D and E material.

N-50 material is made using only prime virgin powder and the material used for this study has a microstructure as represented in Figure 1d; note that the material used for this effort has a slightly larger grain size than the S-200D. While there is a difference in origin of powders, possibly causing a difference in grain size distribution, this does not prohibit comparison of N-50 and S-200D material for effects of different oxide concentrations. N-50 and S-200E can also be compared for influence of grain size if the oxide concentrations are similiar.

The material having the strongest texture in this study is the S-200 cross rolled sheet. The texture can be seen from the basal plane pole figure (Figure 2a). A photomicrograph of this sheet is shown in Figure 2b.

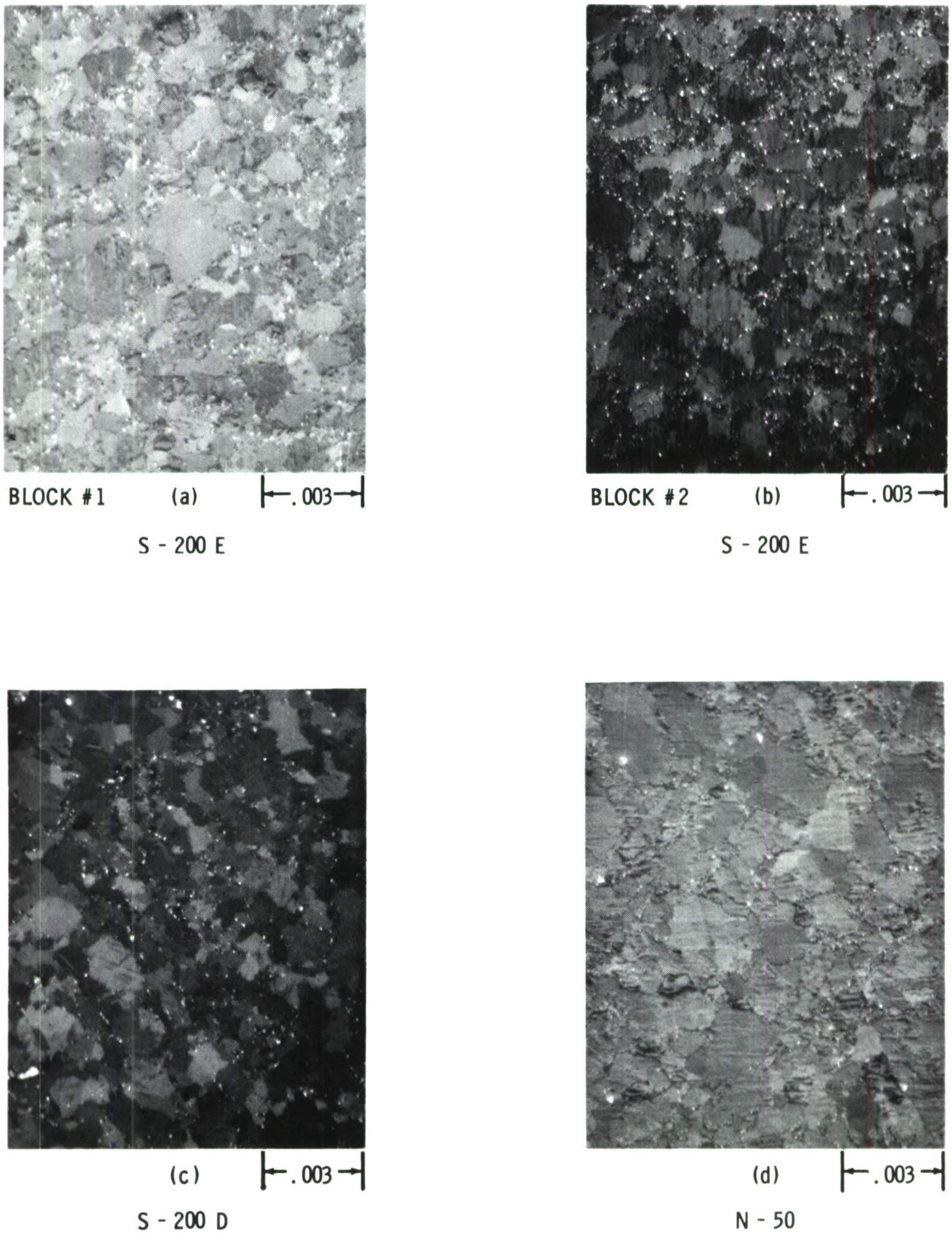
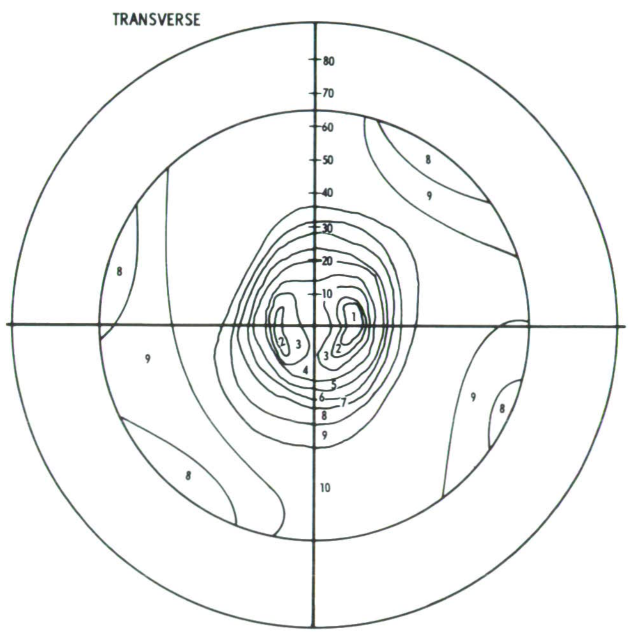


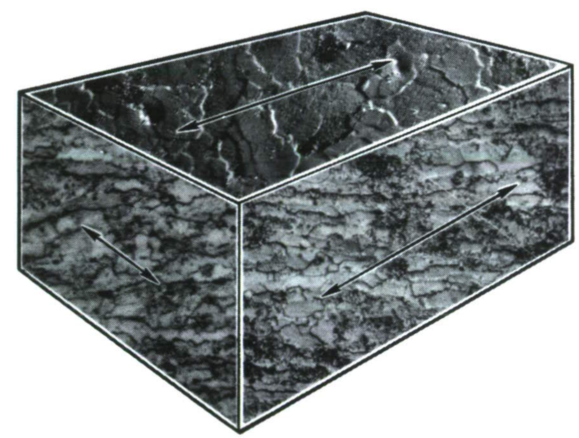
Figure 1 Photomicrographs of Hot Pressed Block Berylliums



(0002) BERYLLIUM POLE FIGURE

RELATIVE INTENSITIES

	Counts		Counts
1	1400 - 1600	6	400 - 600
2	1200 - 1400	7	200 - 400
3	1000 - 1200	8	100 - 200
4	800 - 1000	9	50 - 100
5	600 - 800	10	0 - 50



a. Basal Pole Figure

b. Photomicrograph

Figure 2 S-200 Beryllium Cross Rolled Sheet

The properties of the S-200 hot pressed block and the cross rolled sheet can be compared for the effect of texture differences (primarily fabrication) since the oxide concentration is similar in both materials. Comparing the ingot sheet with the other materials is complicated, because the ingot sheet has a much larger grain size, a lower impurity level and a higher degree of anisotropy than any of the hot pressed block materials. However, where similarities or comparisons are found, they are described.

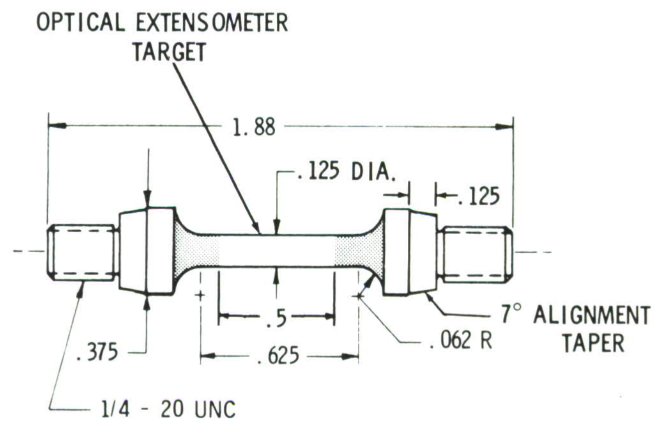
SECTION III

PROCEDURES AND TECHNIQUES

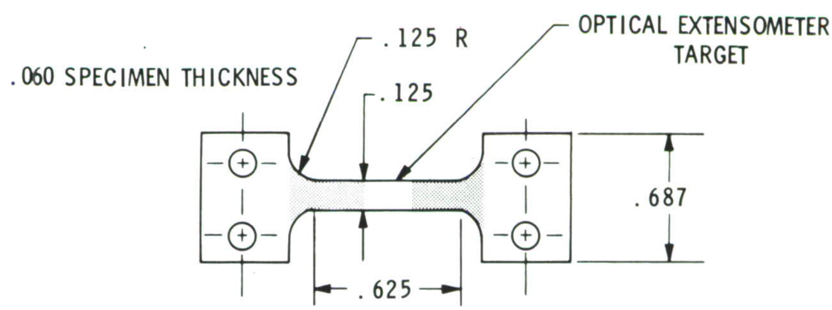
Uniaxial stress tension tests were performed covering a range of strain rates from approximately 10^{-3} to 10^{3} sec^{-1} with N-50 and S-200E material at room temperature and from 10^{-3} to 10^{2} sec^{-1} with all three materials at temperatures of 300°F, 500°F, and 700°F. At least three tests were performed at each testing condition. Specimens from Block No. 1 of the S-200E material showed very erratic ductility at elevated temperature and therefore a limited number of tests using specimens from Block No. 2 were conducted.

Specimen configurations for the medium strain rates (10^{-3} - 10^{2} sec^{-1}) are shown in Figure 3a and b. The specimen used for the high strain rates (10^{2} - 10^{3} sec^{-1}) is shown in Figure 3c. All specimens from the block material were machined with axis transverse to the pressing direction, while specimens from the sheet material were machined with axis transverse to the last rolling direction. The specimens were rough machined to 0.020 inches of the final dimensions and then ground to the final dimension in 0.002 - 0.003 inch cuts. After machining, a 0.001 - 0.002 inch surface layer was chemically etched to remove machining damage using the following etchant at 230°F:

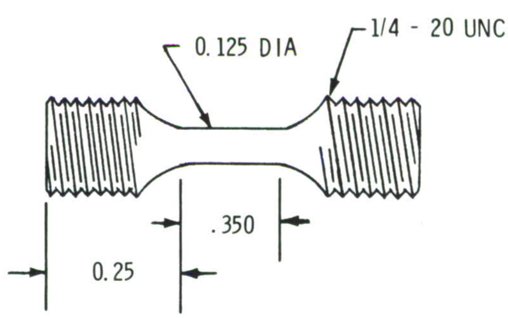
213	gms	Cr_2O_3
1800	cc	H_3PO_4
106	cc	H_2SO_4



a. Tension Specimen for Hot Pressed
Block Material at Medium Strain Rates



b. Tension Specimen for Sheet Material



c. Tension Specimen for High Strain Rate

Figure 3 Test Specimen Configurations

This etchant produced a glossy surface finish and studies of the specimen cross section using optical metallography revealed no machining damage at a depth greater than that removed by the etchant. Further removal of material did not affect test results. However, neglecting the etching had an adverse effect on ductility[1].

The General Motors Medium Strain Rate Machine[3] was used for tests at strain rates between 10^{-3} and 10^{2} sec^{-1}. The alignment of the testing machine was determined using a sample specimen with strain gages mounted in the reduced section at 120-degree intervals around the circumference. The gages were individually monitored as the specimen was stressed to a point just below the elastic limit of the material. Alignment was verified when the three strains were found to be within $\pm$ 1.5% of each other.

A three zone radiant heating oven was used for the elevated temperature tests with each zone individually controlled to minimize temperature gradients throughout the specimen gage length. Chromel-alumel thermocouples were used to measure the testing temperature. Strain was measured using both a Physitech optical extensometer and a foil strain gage (0.125 inch gage length) mounted in the center of the specimen's uniform section. The optical extensometer measured the elonation of the painted target (Figure 3a, b) during the test. Both types of strain instrumentation were used for the room temperature tests, while only the extensometer was used for the elevated temperature tests. The oven had ports to permit viewing the specimen gage length during the elevated temperature tests. In all tests, the ductility reported is the specimen strain to failure measured in the center target area of the uniform gage length.

For the high strain rate tension tests (> 10^2 sec^{-1}), a device utilizing the split-Hopkinson bar approach was used. A complete description of this technique can be found in Reference 4. No elevated temperature tests were conducted and only the N-50 and S-200E were tested using this method.

The use of the device described in Reference 4 has some limitation which should be understood before interpreting the data. Using one dimensional wave analysis, data reduction assumes insignificant axial stress gradients; however, this assumption is valid only after several reflections of the initial stress pulse through the specimen. The speed of sound in beryllium is approximately 5 X 10^5 in/sec. Therefore, the time required for the initial stress wave to be transmitted through and reflected from the end of the specimen is approximately 2 μseconds for a .5 in. long specimen $\left(\frac{1 \text{ in.}}{5\text{x}10^5 \text{ in/sec}}\right)$. Many reflections are required in order to have uniform stress within the specimen and for ten reflections to occur, the limiting strain rate, assuming a maximum strain of 2.0%, is 10^3 sec^{-1} (0.02 in/in)/(10 reflections) (2 μsec/reflection). As the strain rate increases, the data becomes more difficult to interpret due to increased stress nonuniformity. Therefore, the maximum strain rate used for the materials in the present effort was 200-400 sec^{-1}. This range of rates permits a total test time of 50-100μsec when testing a specimen having a 2.0% fracture strain, allowing sufficient time to attain nearly uniform stress along the specimen length. Since the initial portion of the data is difficult to interpret, the yield stress is highly questionable.

SECTION IV

EFFECT OF OXIDE CONTENT

The beryllium oxide concentration of the materials in the present study and those in Reference 1 range from 0.03 to 7.0%. However, the materials with other parameters of sufficient similarity, namely grain size and texture, limit the study of oxide concentration effects to N-50, S-200E Block No. 2, S-200D and I-400.

The large influence of texture on the mechanical properties of sheet materials makes the study of oxide content effect difficult. The ingot sheet has a much larger grain size and a higher degree of texture than any of the hot pressed block materials[1]. The beryllium sheet (S-200) also has a much sharper texture than any of these materials.

The S-200E Block No. 1 was not used in the comparison for the influence of oxide content since it exhibited erratic behavior at elevated temperatures. This erratic behavior was in the strain to fracture and became very pronounced at 700°F. In some tests no measureable plastic deformation (< 0.1%) was observed when the specimen fractured, and in none of the tests at 700°F was the strain to fracture observed to be greater than a few percent. This is in contrast to the ductility of the S-200D hot pressed block tested previously[1] where a maximum ductility of 36% at 10^{-3} sec^{-1} was observed. Optical and electron microscopy of the bulk material microstructure and of the fracture surfaces revealed no explanation for this observation. Since the behavior could not be explained, it was thought unwise to use the room temperature

data in any of the comparison studies. While comparing the mechanical properties for the influence of oxide in these materials, some differences in grain size as well as oxide exist and should be considered as possible variables.

Although the brittle to ductile transition temperature is not very distinct for these materials, the temperature where increased ductility was observed increased with oxide content at the low strain rate (10^{-3} sec^{-1}) (Figure 4). The tests at higher strain rates indicate a somewhat similar trend, (see Appendixes B, C and Reference 1). The I-400[1] material at the higher strain rates does not show an increase in ductility with increasing temperature from 72 to 700°F. Since 2.0 and 0.9% are both upper limits on oxide concentration for S-200D and N-50, the spread between the actual oxide concentrations could be considerably different than 1.1%. Because of fabrication techniques, there is a greater probability the difference is less than 1.1%.

In general, there is a tendency for ductility to increase with decreasing oxide content, but the N-50 does not have the high ductility of the S-200D material. This difference between N-50 and S-200D could be attributed to the differences in size or distribution of grains.

Yield stress at 72 and 700°F and at strain rates of .002 and 20 sec^{-1} are plotted against beryllium oxide concentration in Figure 5. Clearly, increased oxide concentration raises the yield stress. The ingot sheet does not show the same general trends as the other materials; this is assumed to be the result of the texture in the sheet.

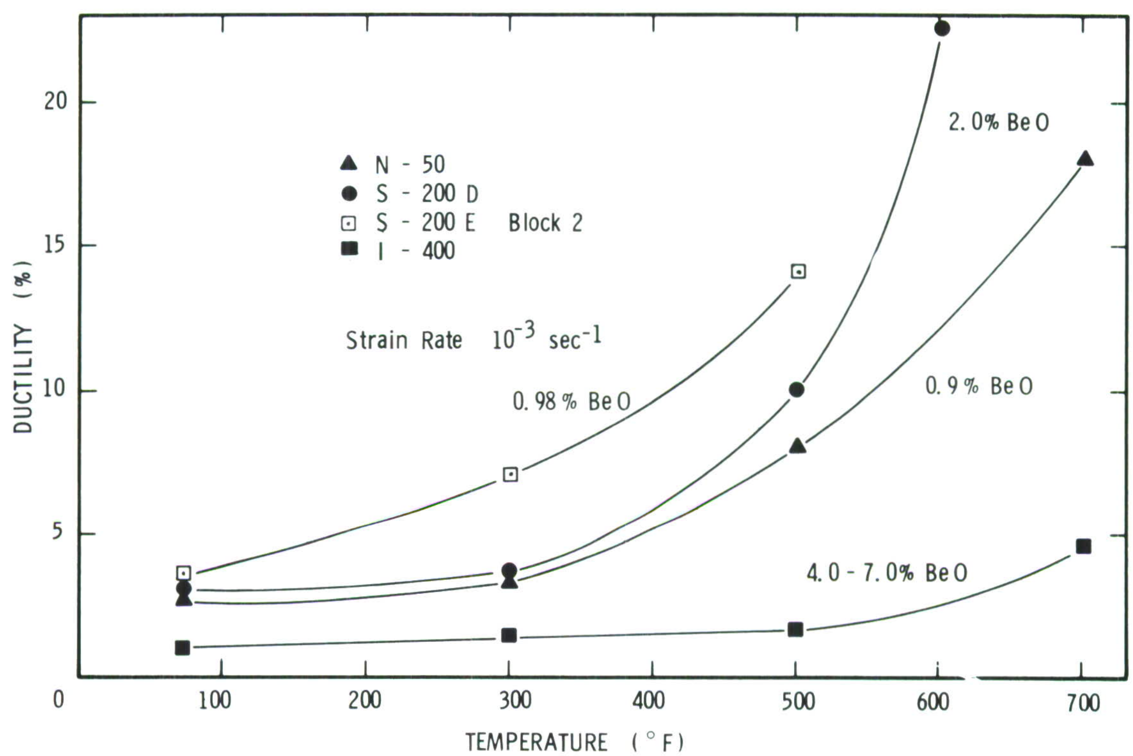


Figure 4 Effect of Oxide Content on Ductility of Three Grades of Beryllium

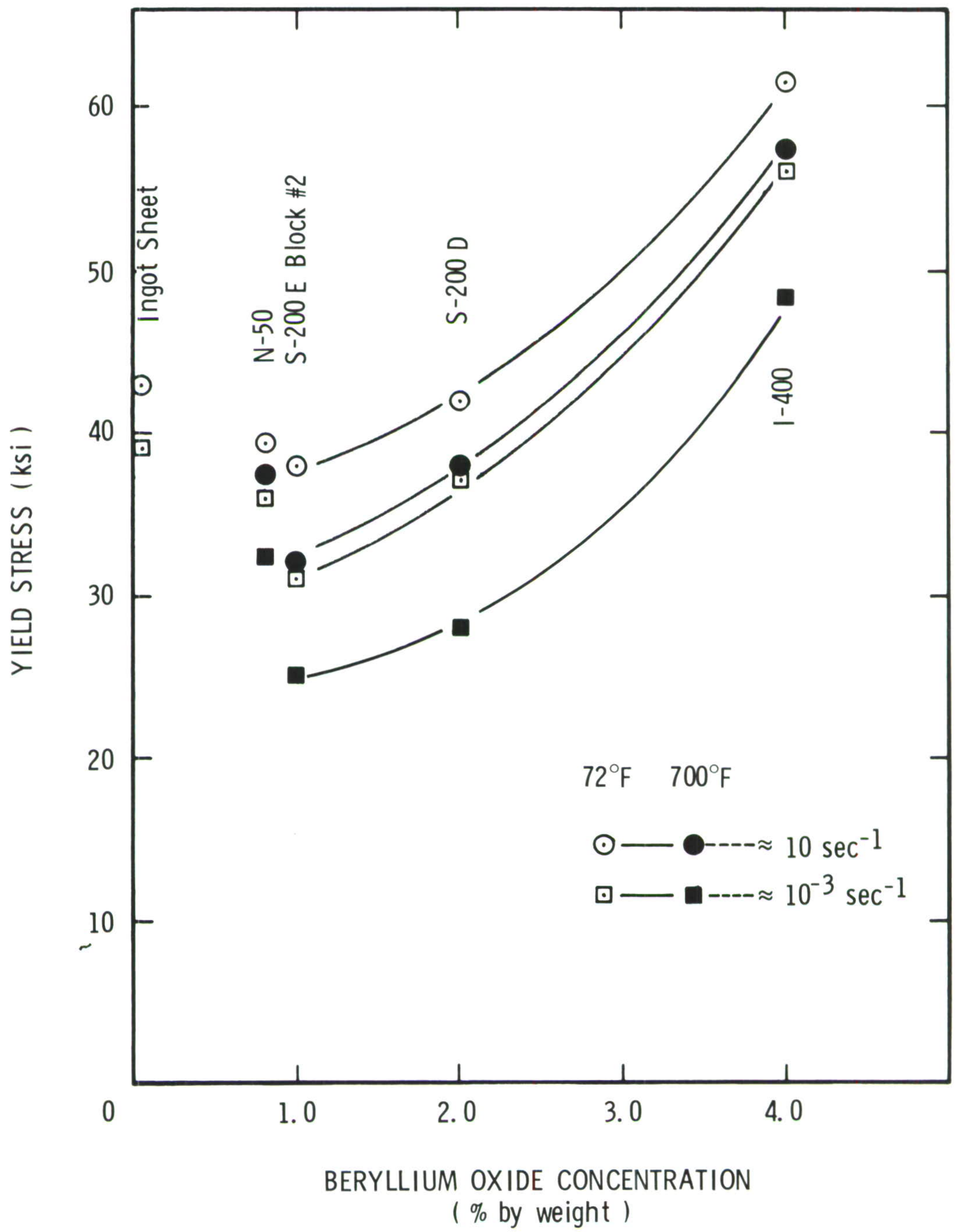


Figure 5 Ultimate Strength of Berylliums with Different Beryllium Oxide Content

SECTION V

EFFECT OF TEXTURE

The effect of texture can be seen if the S-200 cross rolled sheet mechanical properties are compared with those of the more isotropic hot pressed block, S-200D, having a similar oxide level. The temperature where maximum ductility is observed is lower in the rolled sheet (Figure 6). In general has greater ductility, especially at the lower temperatures. This increased ductility is undoubtedly due to the sheet being highly textured, where basal planes are nearly parallel to the plane of the sheet. Therefore, basal slip and subsequent frac-

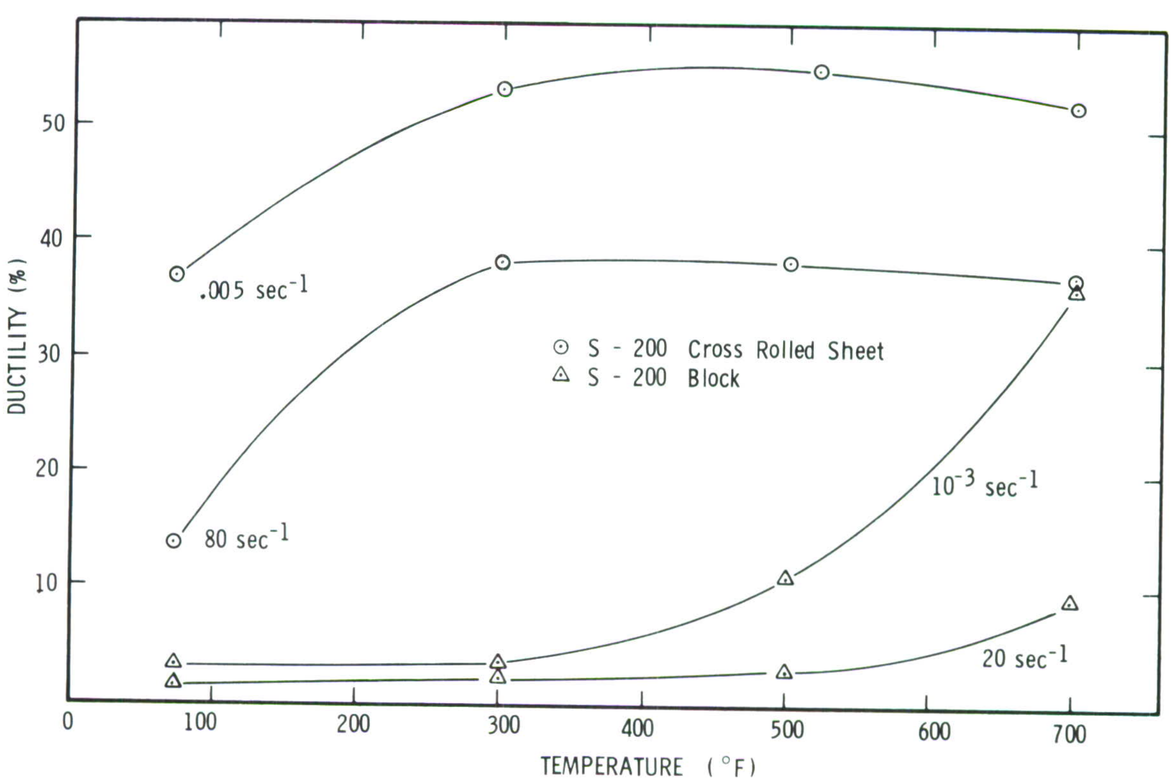


Figure 6 Effect of Texture on Ductility

ture are suppressed and a more ductile prism slip mode is encouraged.

While the cross rolled sheet has good uniaxial ductility in the plane of the sheet, its ductility under any loading system requiring sheet thinning is poor. The texture, which permits prism slip in the plane of the sheet, also inhibits thinning. A measure of this resistance to thinning is the parameter R, where R is the ratio of width to thickness strain in a tensile test. The R value for this textured material was measured to be between 15 and 30 at room temperature and never decreased below 7.5 at temperatures up to 700°F. The large difference between the width and thickness strain at elevated temperature is seen visually in Figure 7, where little thinning is observed even in the region where large strains occurred.

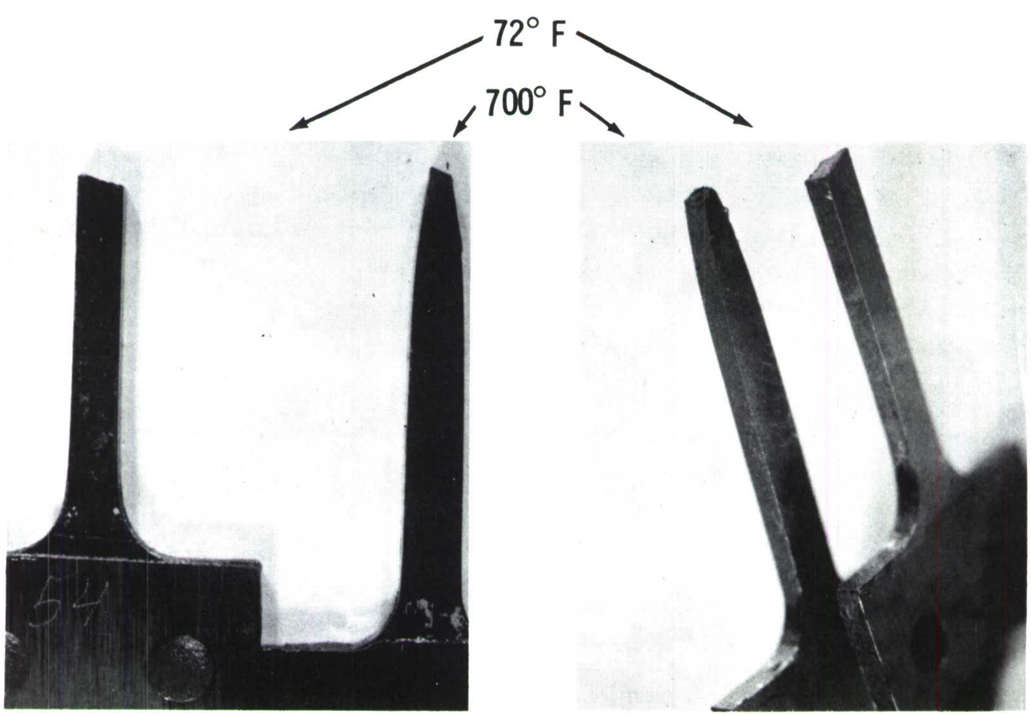


Figure 7 Fracture Angle of S-200 Sheet Specimens at Low Strain Rates

The ductility reported is the strain to fracture and is therefore greatly influenced by the amount of necking or unstable straining in the specimen gage length prior to fracture. The sharp increase in ductility of the sheet with increasing temperature is accompanied by necking. The strain in the localized region of the neck is much higher than the total measured ductility. However, the strain in the sheet at the ultimate stress level does not vary as significantly with temperature as does the measured total ductility (Figure 19).

The fracture surface of the sheet was inclined at an angle of 75° to the tensile axis (Figure 7) and this angle did not change with strain rate or temperature. Conrad and Cooke[5] found the angle, for different grades of beryllium, varied from 45° to 75° as the ductility changed. Fractographs taken with a scanning electron microscope of S-200 sheet and hot pressed block (S-200D) are shown together in Figure 8. The higher ductility of the sheet is reflected in the ductile fracture appearance (dimples at the elevated temperature and fibrous tearing at room temperature). Fracture in the hot pressed block, however, varies from cleavage at room temperature to a mixed cleavage-tearing mode at the elevated temperature.

Although the ultimate strength of the sheet and block have large differences at the low to moderate temperatures, it can be seen from Figure 9 that these strength differences become less significant as the temperature is increased. This is a result of a rapid decrease in the Critical Resolved Shear Stress (CRSS) for prism slip with increased temperature, while the CRSS for basal slip decreases less rapidly with temperature.

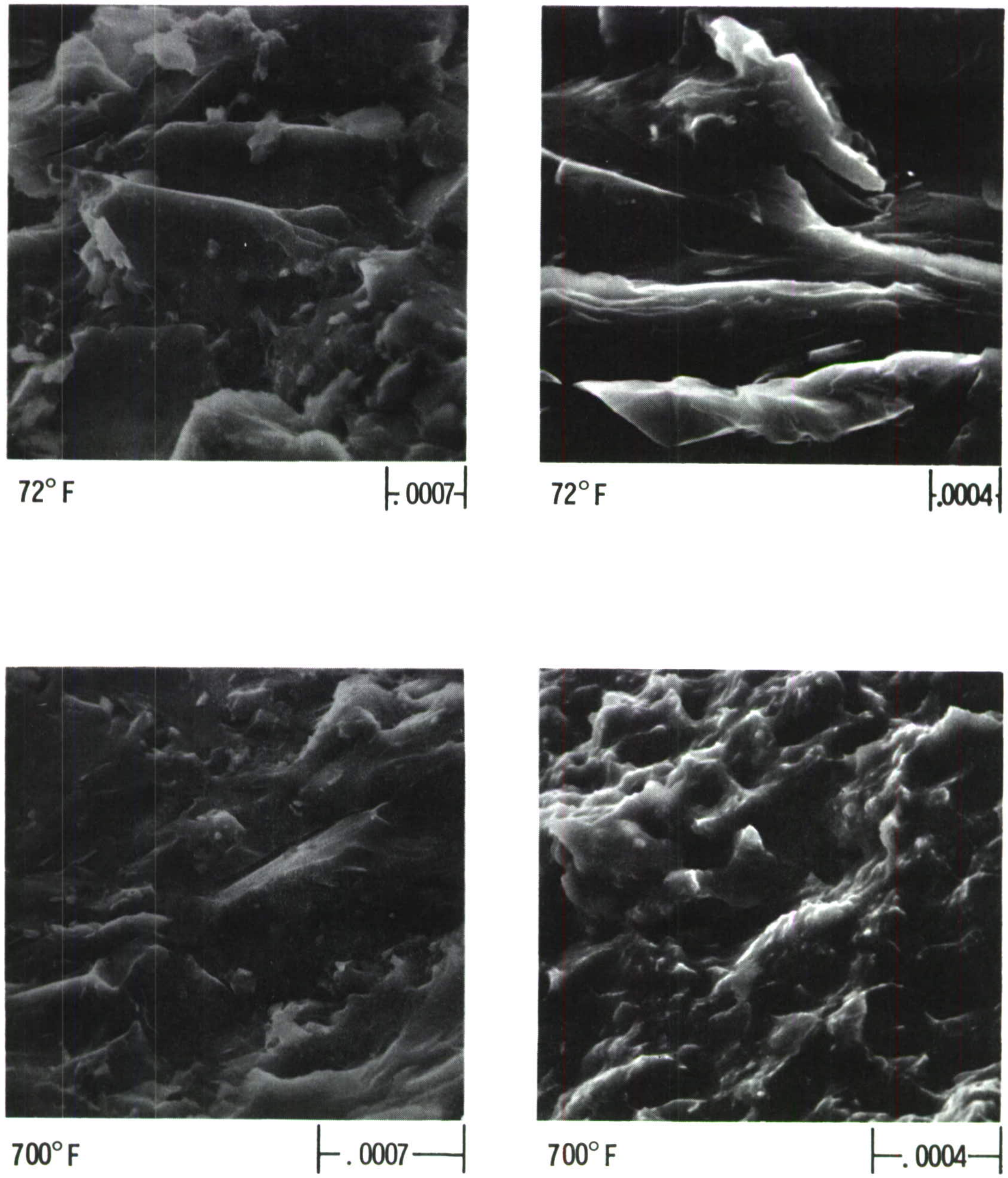


Figure 8 Fractographs of Hot Pressed Block and Textured Sheet Material

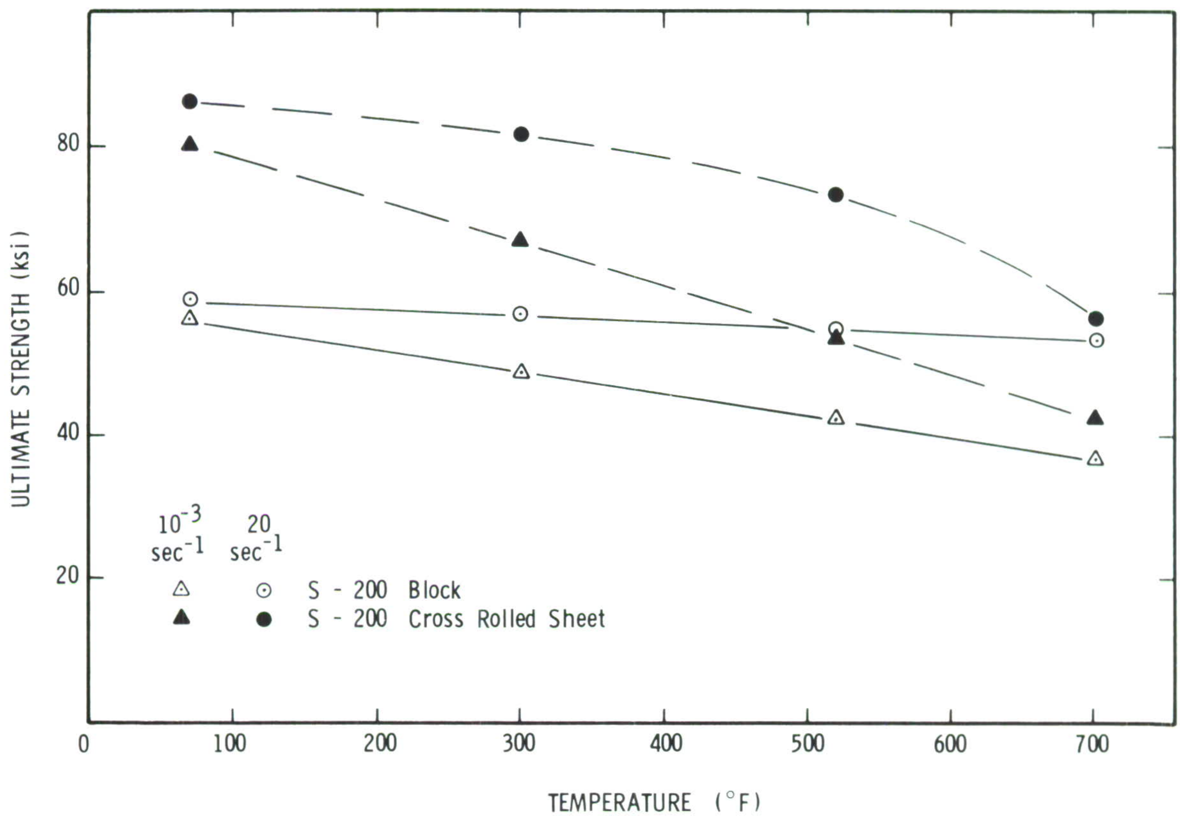


Figure 9 Ultimate Strength of Hot Pressed Block and Textured Sheet Material

SECTION VI

EFFECT OF GRAIN SIZE

It was not possible to use the S-200E and S-200D materials as initially planned for grain size comparison. As mentioned earlier the first S-200E block obtained exhibited very erratic and limited ductility at the elevated temperatures. Therefore, a second block of S-200E was obtained (oxide content of 0.98%). This material could be compared with N-50 grade for effects of grain size since the oxide concentrations were quite similar and the grain size differed by a factor of two.

Figure 10 exhibits the difference in ductility between S-200E (18μ grain size) and N-50 (40μ) at about 10^{-3} sec^{-1}. Note that the N-50 material has a lower ductility although it has a slightly lower oxide level. The brittle-ductile transition appears to be slightly lower for the smaller grain material. The data in Appendixes B and C indicate a similar trend for higher strain rates.

Although ingot sheet(1) has a low BeO concentration and has a stronger texture than the hot pressed block materials, an extremely low ductility is observed in the plane of sheet. It was found previously(7,8,9,10), as well as in the present effort, that strong texture and high purity tend to increase ductility. Although these factors would tend to increase the ductility of the ingot sheet (100-300μ), it exhibits a lower ductility than S-200D, N-50, or S-200E. Fractographs of the ingot sheet (Figure 11) show a cleavage failure with very little

evidence of ductility. This disparity could be rationalized as resulting from the large grain size difference between the materials.

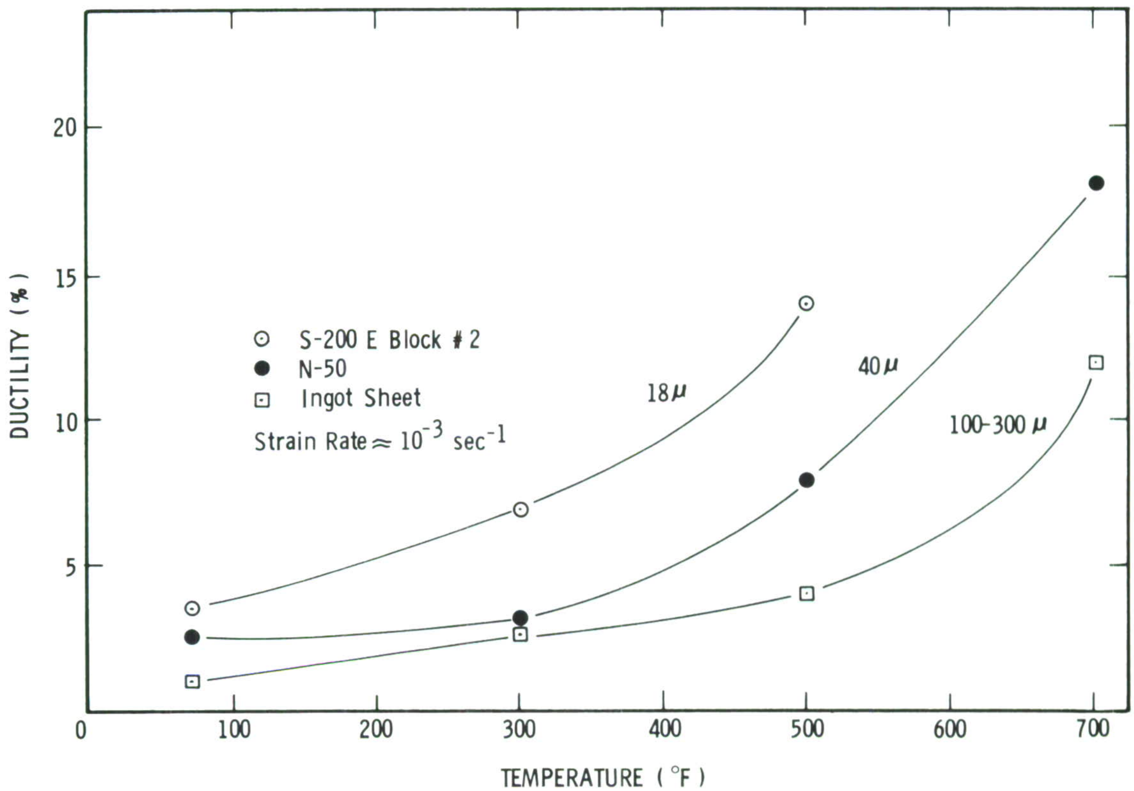
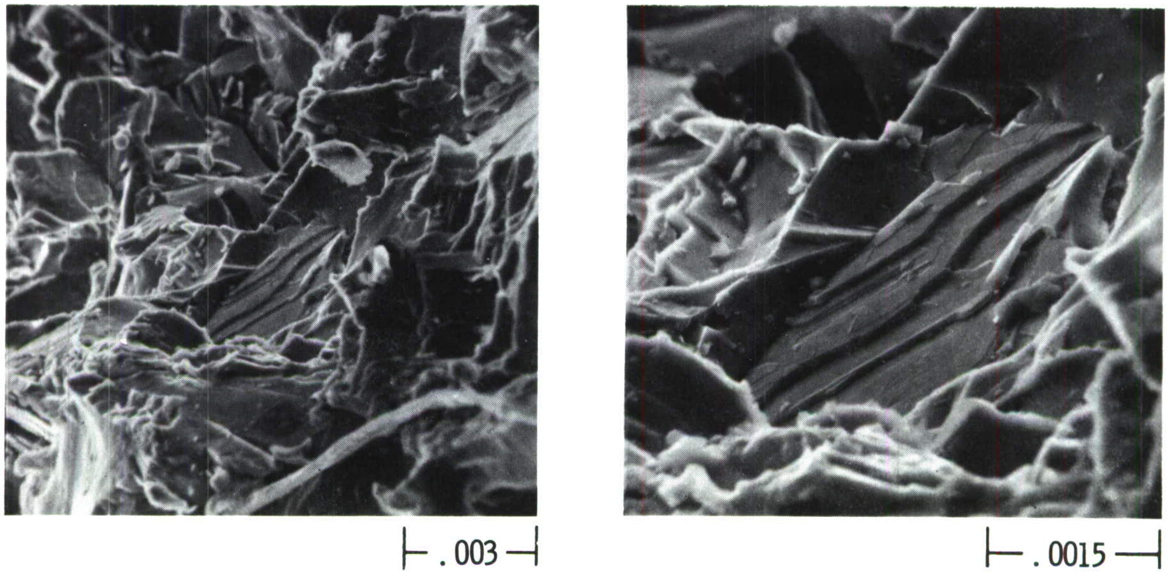


Figure 10 Ductility of Three Grades of Beryllium Having Different Grain Size

Figure 12 shows the effect of grain size on two grades of beryllium. These materials exhibit different yielding processes, the N-50 exhibiting a sharp yield drop which increases with strain rate and the S-200E Block 1 exhibiting no yield drop. Generally it can be concluded the effect of grain size does not change the flow stress by an amount greater than



72°F 10^{-3} sec^{-1}

Figure 11 Fractographs of Ingot Sheet Beryllium

material scatter, although it appears to influence ductility significantly. This generalization applies only to the grain sizes of the materials studied in the present effort and in Reference 1.

Conrad and Cooke[5] found an important variable was the subgrain size when considering the mechanical properties of sheet material although the optical grain size was constant. This parameter could also be important when looking at the more isotropic block materials but was not considered in the present effort.

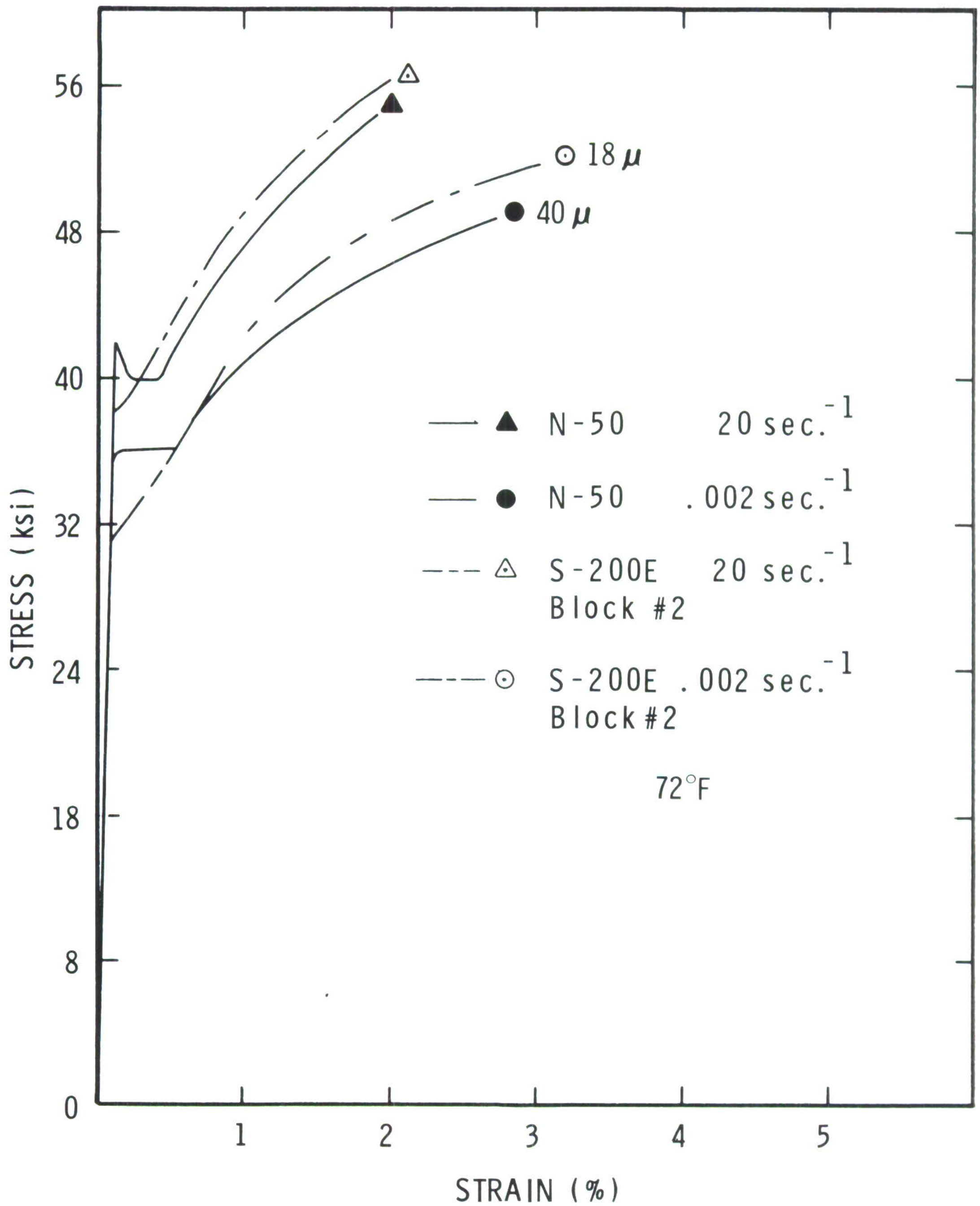


Figure 12 Strength of Two Grades of Beryllium Having Different Grain Size

SECTION VII

EFFECT OF STRAIN RATE AND TEMPERATURE

The ductility of the various grades of beryllium tested was affected by a change in strain rate. Figure 13 exhibits a greater influence of strain rate on ductility at 500°F than at room temperature. It should be cautioned that in tests using a different specimen configuration (10^2 - 10^3 sec^{-1}), the geometric difference should be considered when comparing the mechanical properties at this rate with those at lower strain rates. The results of other temperatures are given in the Appendixes.

The flow stress at several percent strain versus strain rate is shown in Figure 14. The strain rate sensitivity (indicated by the slope of the curves), in general, increases at the higher rates and temperatures. The effect of strain rate on the yield stress follows the same general trends and can be determined from Figure 5 (a larger change in flow stress due to strain rate at 700°F than at 72°F). Within material and experimental scatter, at both 72°F and 700°F, the differences between the yield stress at a rate of approximately 10 sec^{-1} (σ_{10}) and that at a rate of 10^{-3} sec^{-1} ($\sigma_{.001}$) is independent of oxide concentration and increases with increasing temperature. It is interesting and significant that the strain rate sensitivity of both the ductility and yield stress of the hot pressed block material tends to be larger at the higher temperature.

It was shown by previous investigators that flow stress can be broken into a thermally activated and an athermal component[11,12].

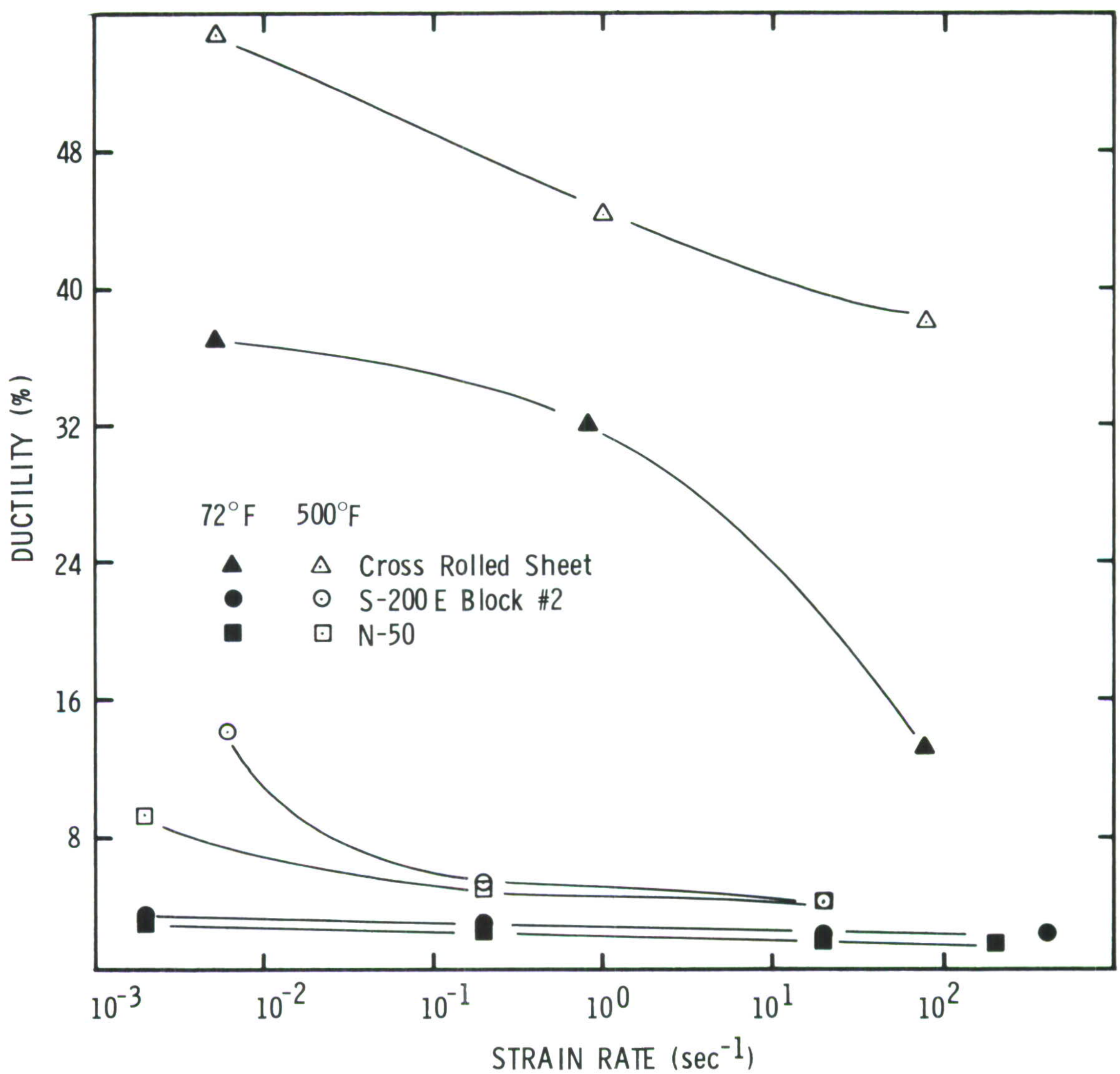


Figure 13 Decreased Ductility of Beryllium with Increased Strain Rate

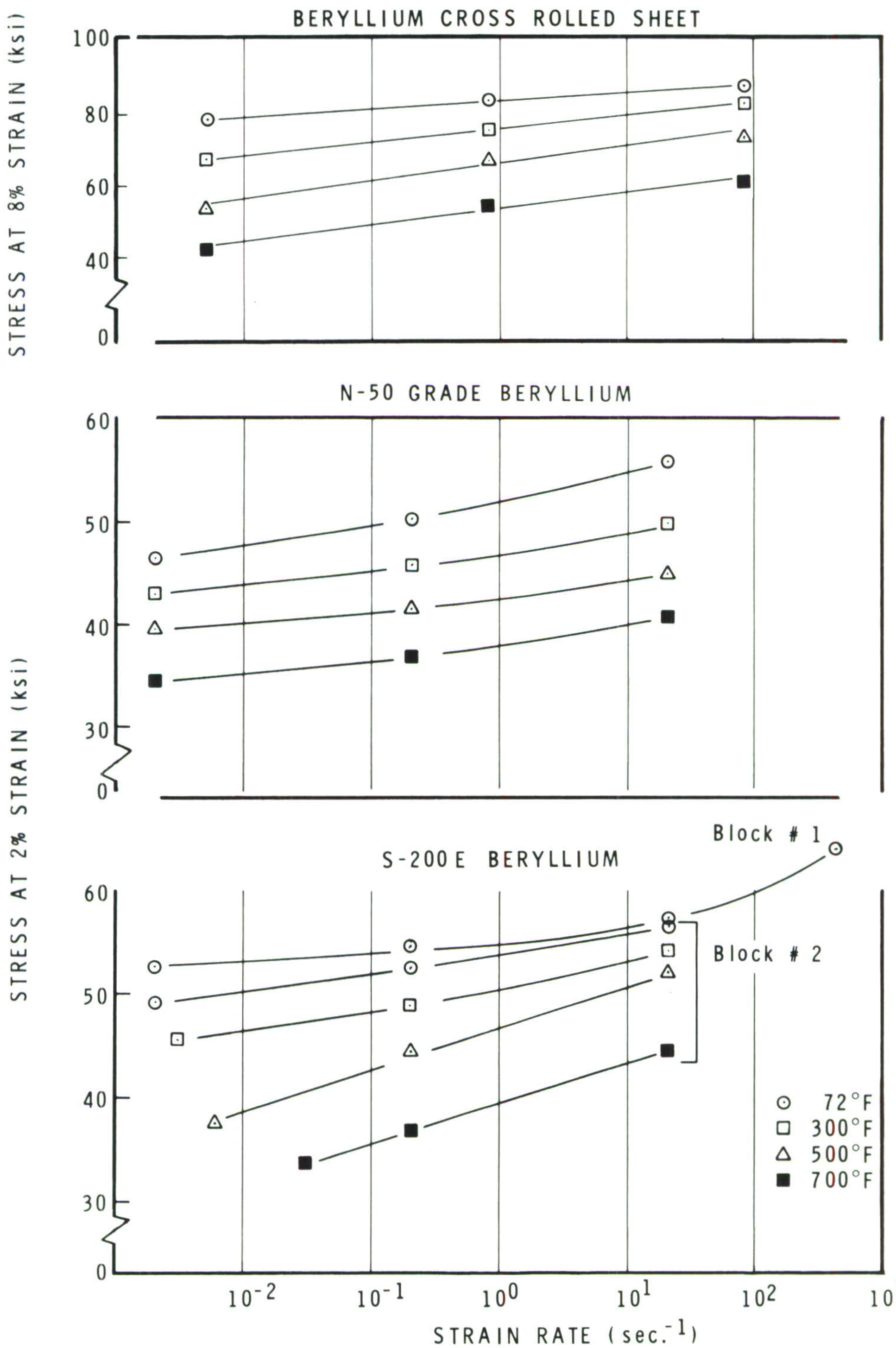


Figure 14 Flow Stress versus Strain Rate for Three Berylliums

The result that $\sigma_{10} - \sigma_{.001}$ is independent of oxide concentration (indicated by the parallel curves of Figure 5) is equivalent to the statement that oxide raises the athermal component of flow stress. A similar independance of oxide concentration on the thermal component is observed if flow stress is varied by changing the temperature from 72 to 700°F with the strain rate held constant; this also indicates the thermal component of flow stress is constant with oxide concentration within material and experimental scatter.

The result that the thermal component is independent of the oxide concentration is similar to observations seen in aluminum alloys in the "0" temper. Higher alloying raised the athermal component only[13] however, in both of these cases, the higher purity materials do have higher fractional or normalized rate sensitivity (defined as $\frac{\sigma_{10} - \sigma_{.001}}{\sigma_{.001}}$) resulting from lower flow stresses in the higher purity materials.

SECTION VIII

CONCLUSIONS

The following conclusions can be drawn from the observation of data acquired during this program:

1. For strain rates above 20 to 50 sec^{-1}, interpretation of stress/strain data is difficult. Yield stress measurements using the split-Hopkinson bar are highly questionable since a uniform state of stress is not achieved during the initial portion of the test. For beryllium where brittle type fractures occur near 2% strain, strain rates should not exceed approximately 400 sec^{-1} for valid interpretation of flow stress in uniaxial stress tests.

2. The ductile-brittle transition temperature increases with BeO content, although total strain-to-fracture decreases with the same increase in BeO. This observation is seen at strain rates up to 20 sec^{-1}.

3. Increasing BeO raises the flow and ultimate stress, generally, at temperatures up to 700°F.

4. The texture of cross rolled sheet changes the mechanical properties to a much larger degree than any other parameter. Flow stress is greater for the strongly textured material at lower temperatures but the difference becomes less significant at elevated temperatures. Uniaxial ductility is greatly enhanced and the increase in ductility is accompanied by the onset of necking at elevated temperature.

5. The ductility is sensitive to grain size and decreases with increased grain size. The ductile-brittle transition temperature is lower for the finer grained materials.

6. The effect of grain size on yield and flow stress is too small to draw any conclusions from the materials tested in this report, this being a result of the grain size influence being marked by the variables, such as BeO concentration, texture, etc.

7. The ductility is adversely affected by an increase in strain rate and becomes more pronounced at higher temperatures.

8. The thermal component of stress is independent of oxide content.

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APPENDIXES

APPENDIX I

S - 200 CROSS ROLLED BERYLLIUM

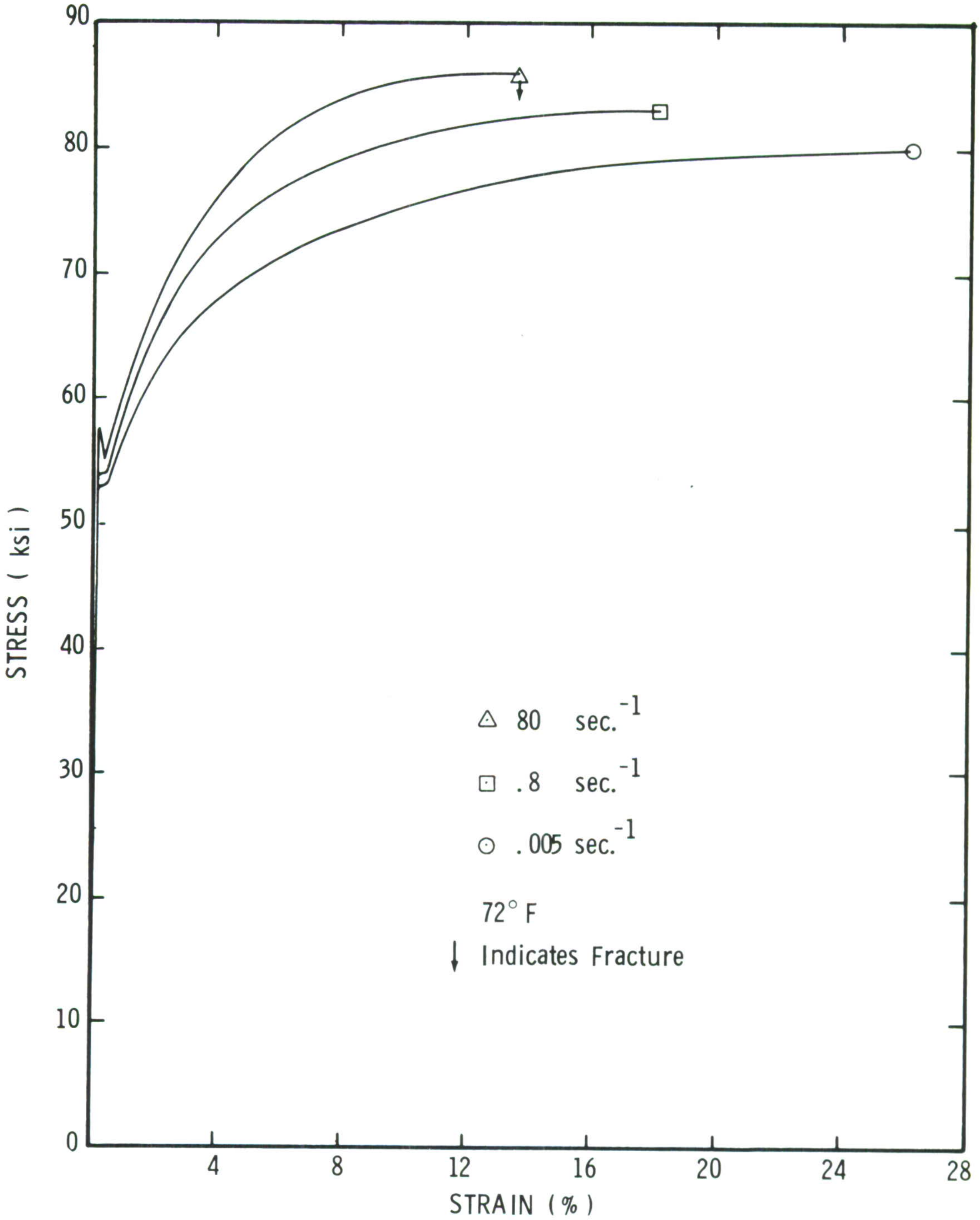

Figure 15 Tension Tests of S-200 Sheet Beryllium at 72°F

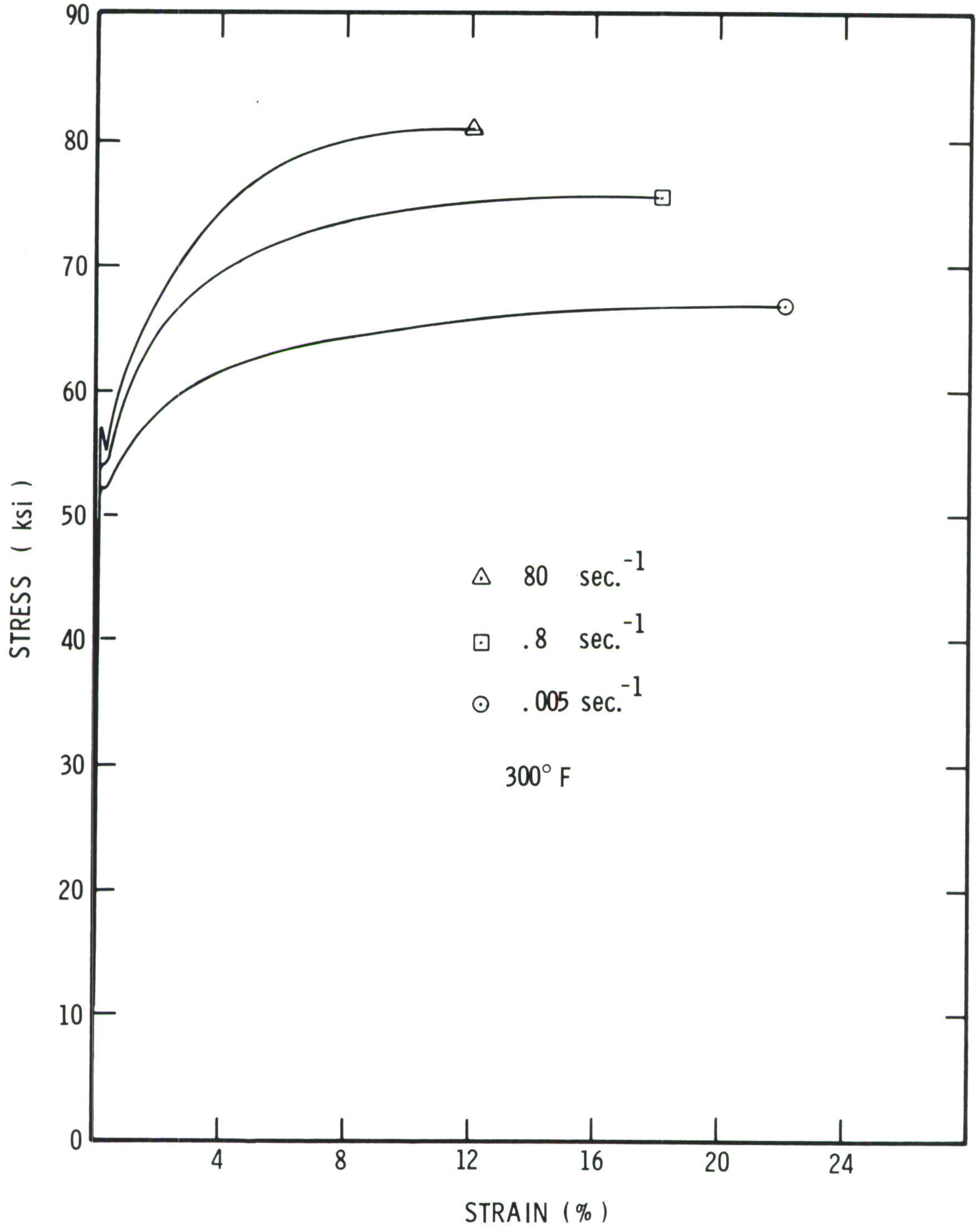

Figure 16 Tension Tests of S-200 Sheet Beryllium at 300°F

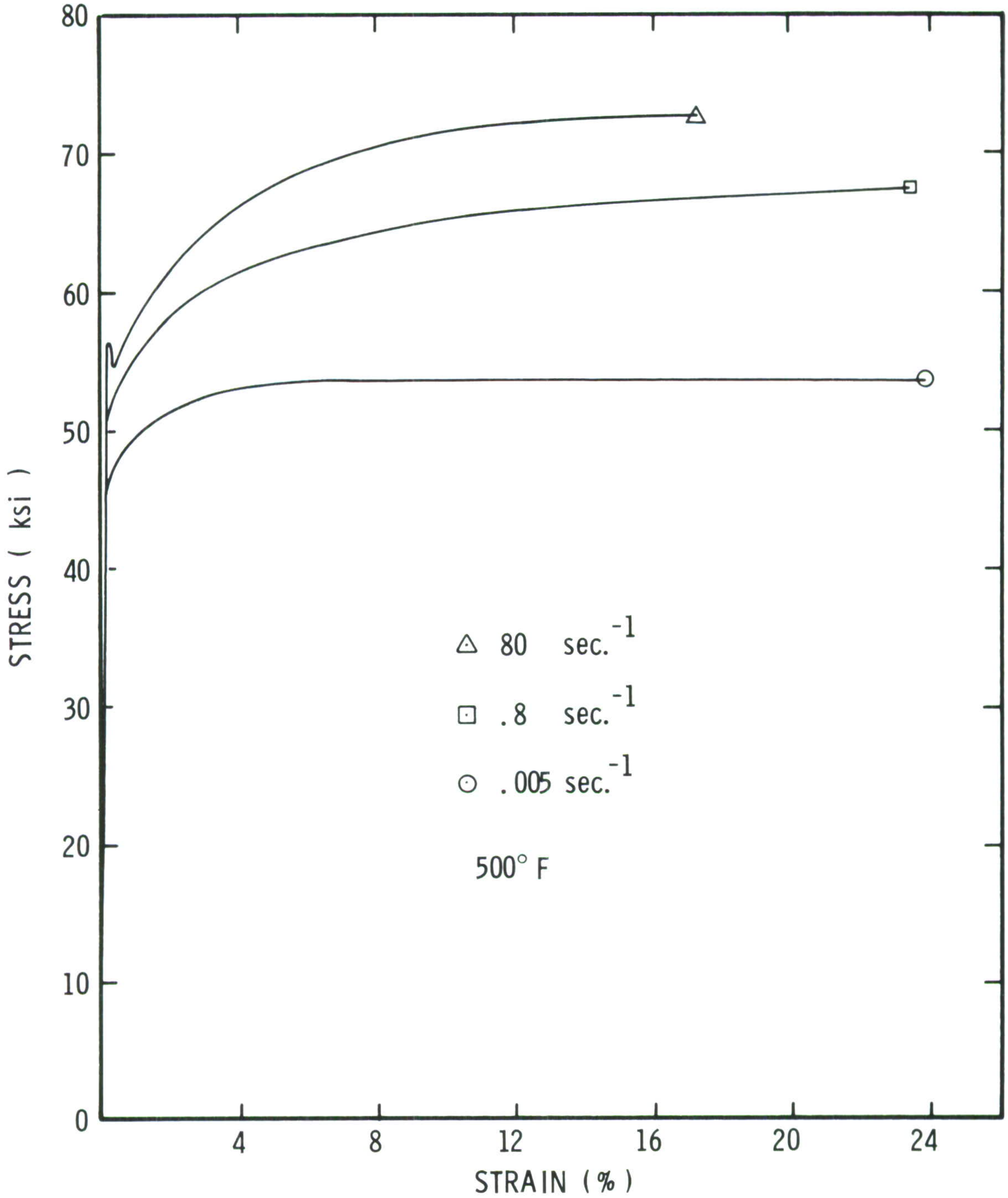

Figure 17 Tension Tests of S-200 Sheet Beryllium at 500°F

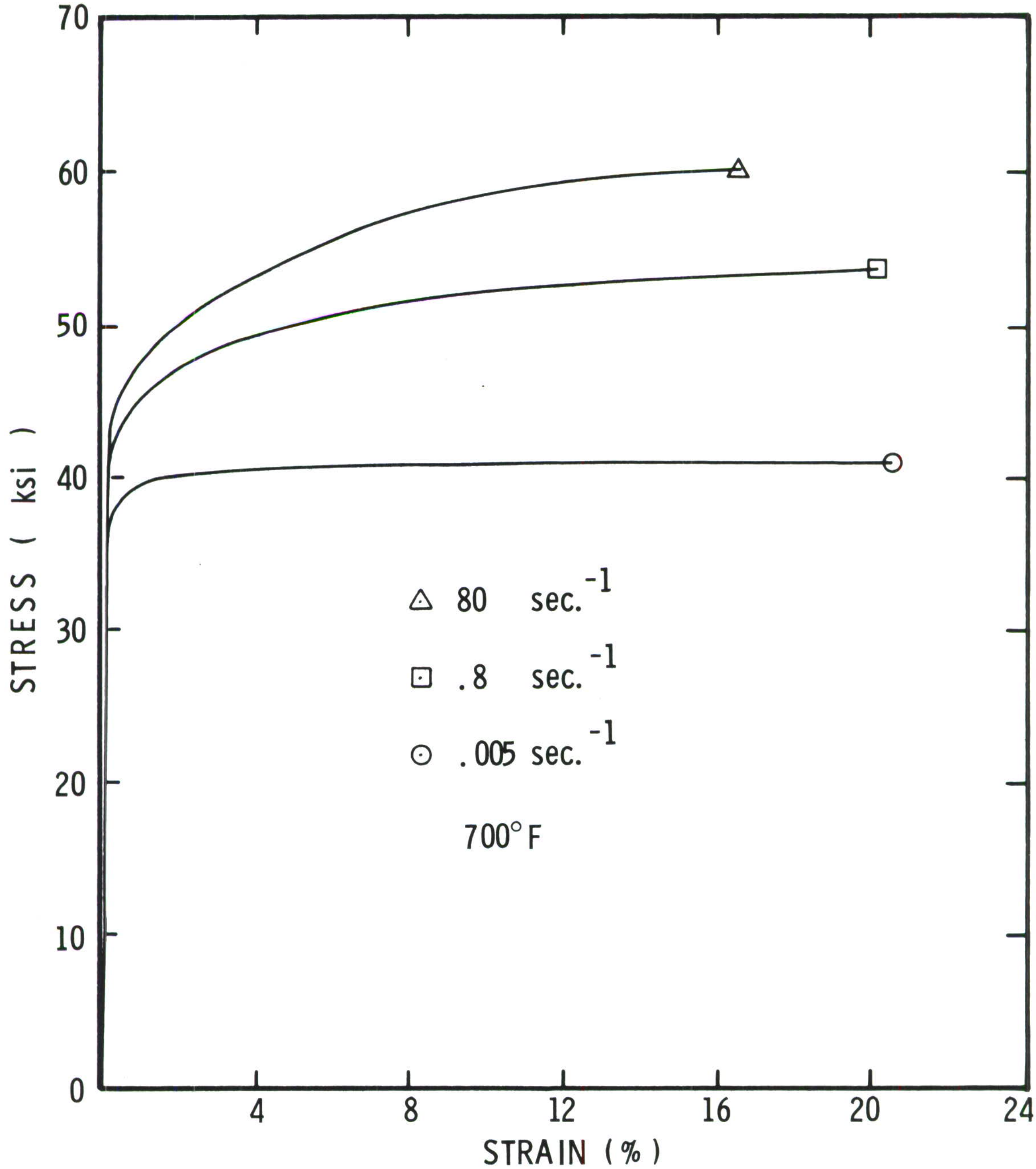

Figure 18 Tension Tests of S-200 Sheet Beryllium at 700°F

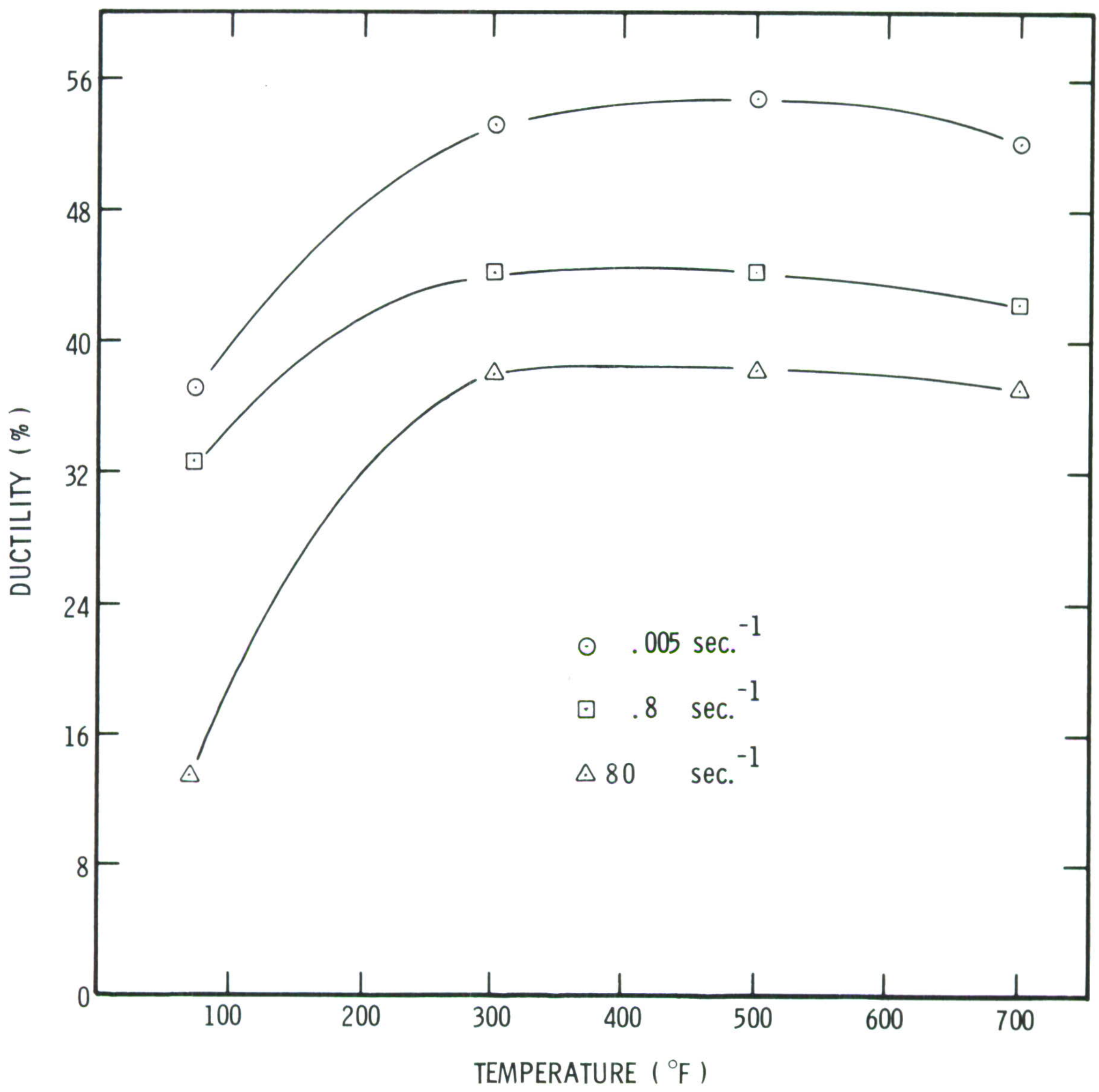

Figure 19 Ductility of S-200 Beryllium Sheet

APPENDIX II

N - 50 BERYLLIUM

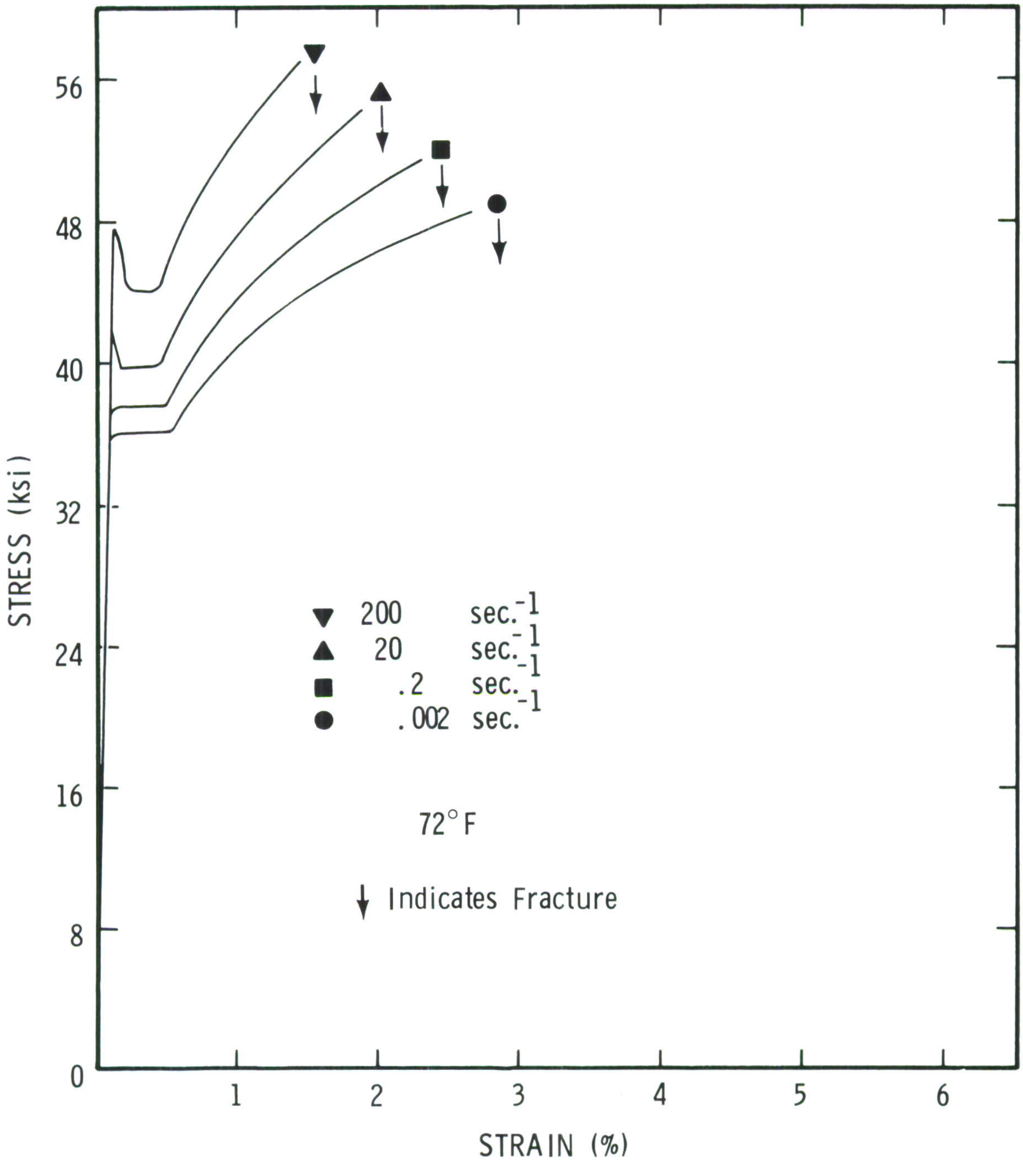

Figure 20 Tension Tests of N-50 Beryllium at 72°F

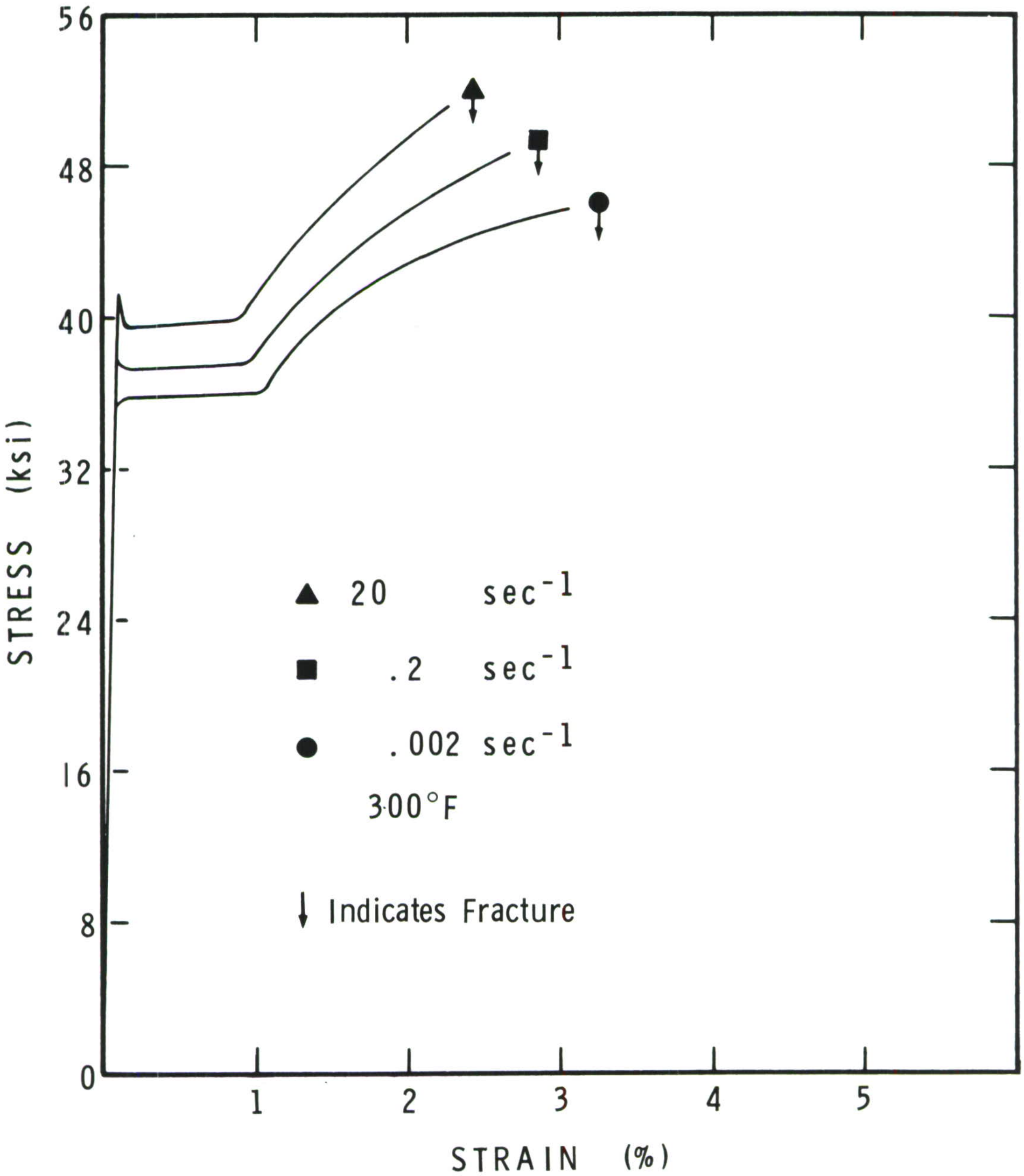

Figure 21 Tension Tests of N-50 Beryllium at 300°F

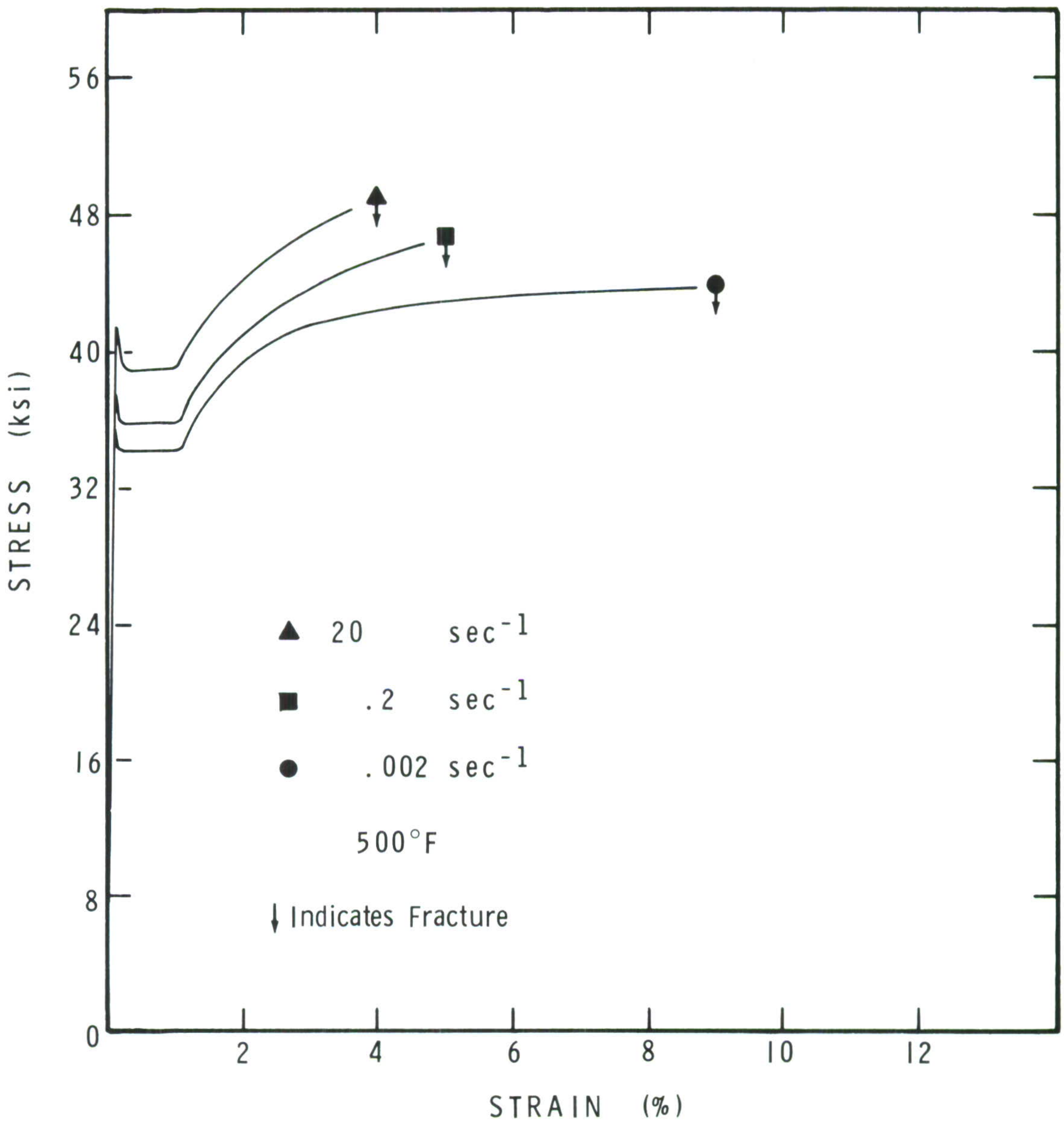

Figure 22 Tension Tests of N-50 Beryllium at 500°F

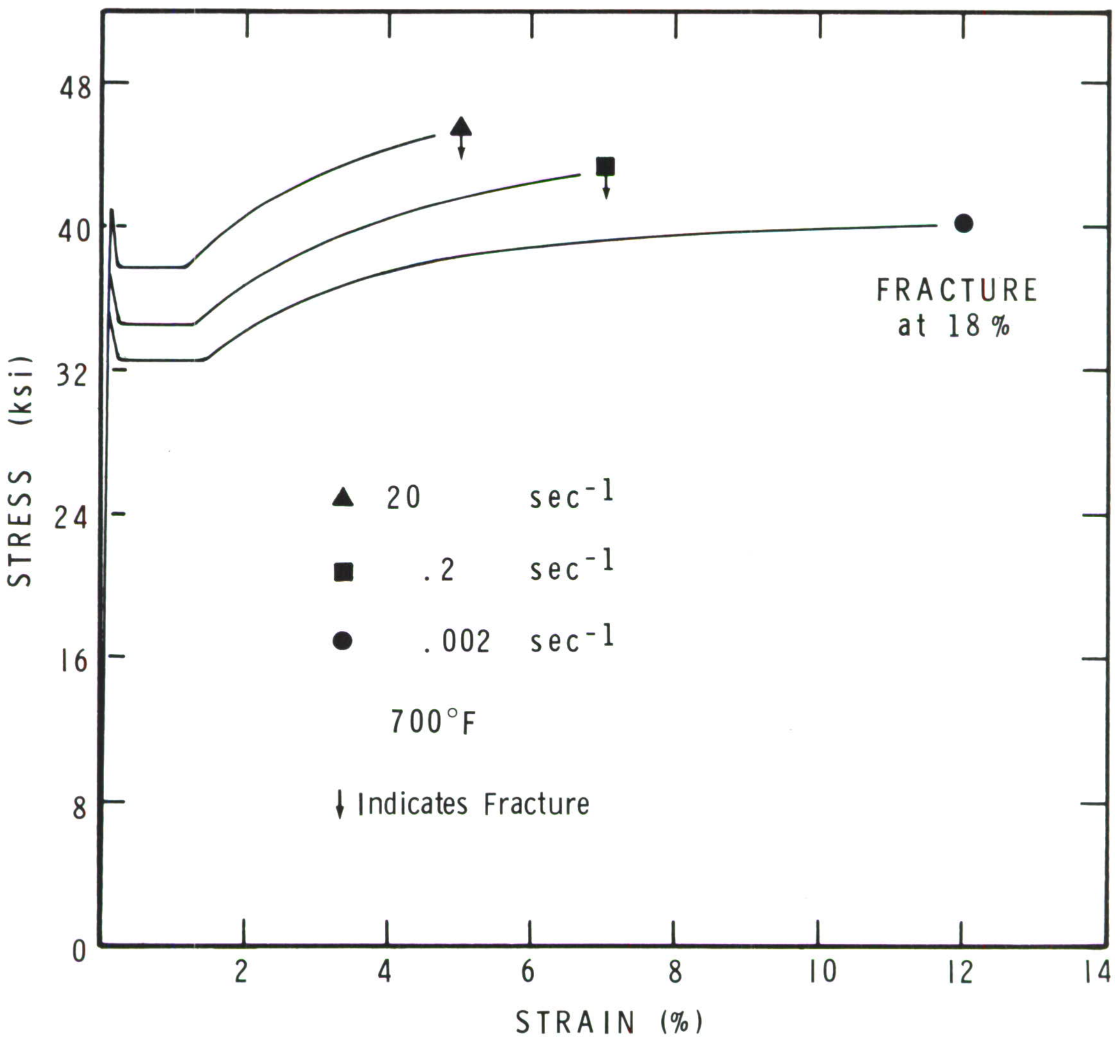

Figure 23 Tension Tests of N-50 Beryllium at 700°F

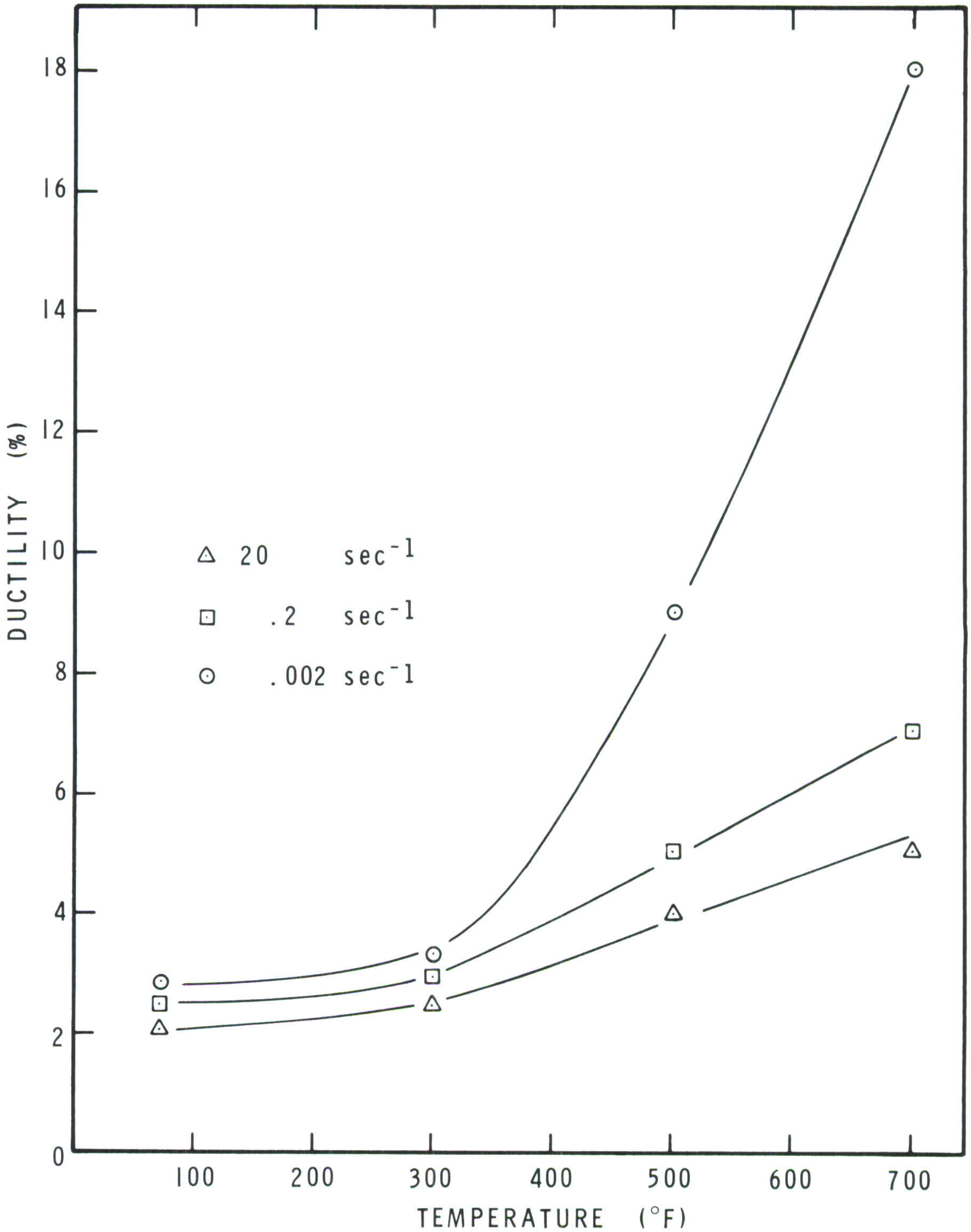

Figure 24 Ductility of N-50 Beryllium

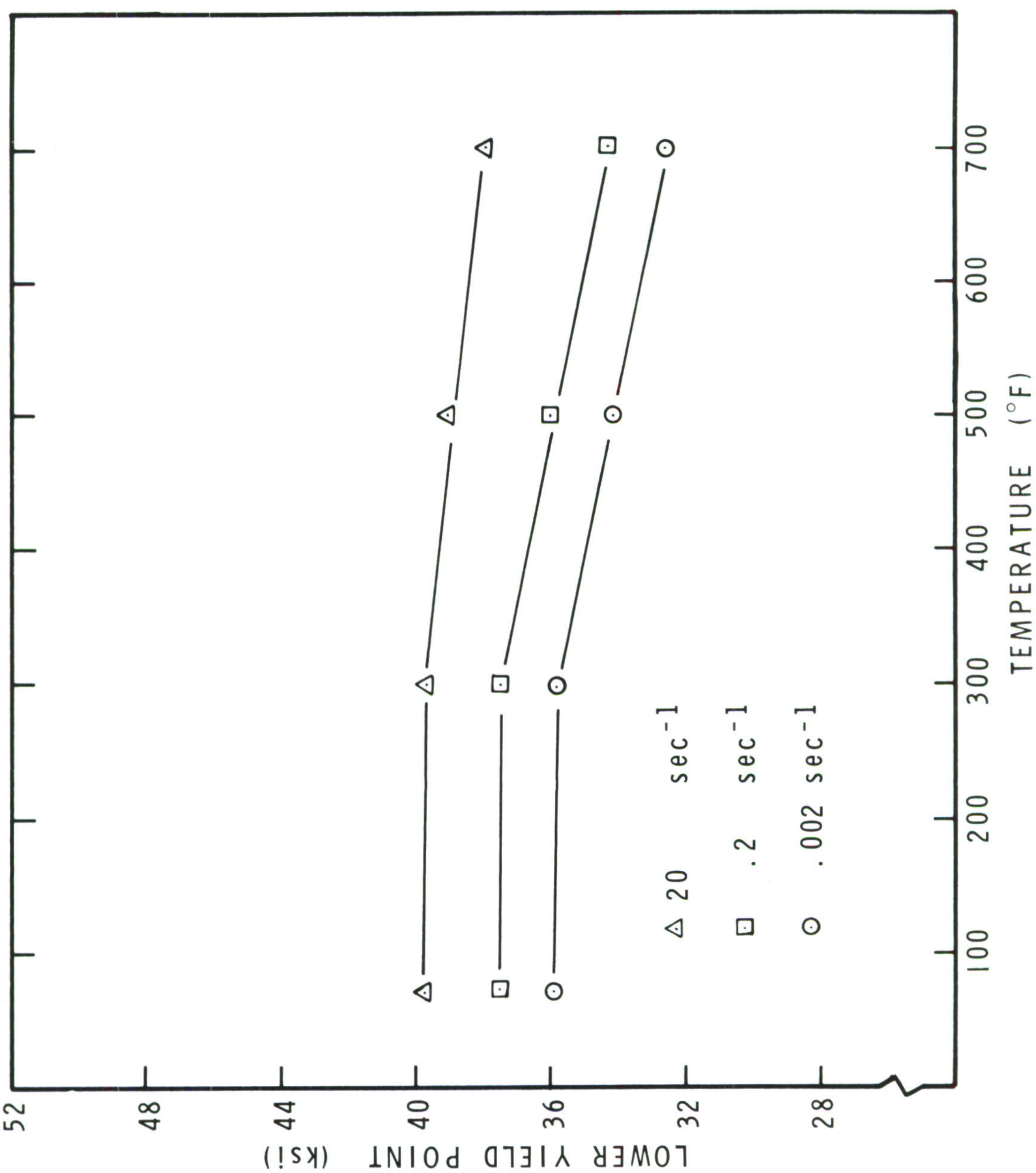

Figure 25 Yield Point of N-50 Beryllium

APPENDIX III

S - 200 E BERYLLIUM

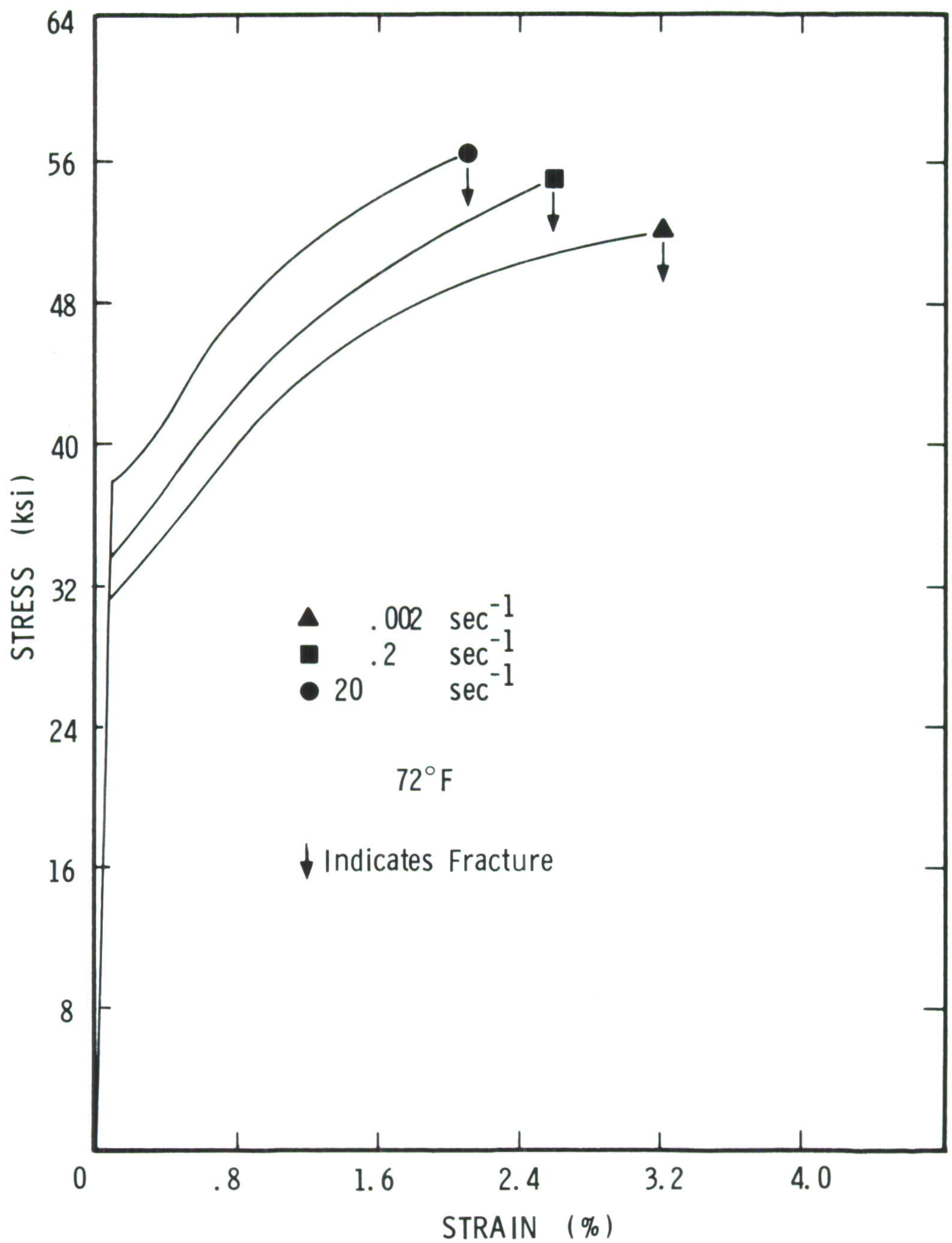

Figure 26 Tension Tests of S-200E Beryllium at 72°F (Block #2)

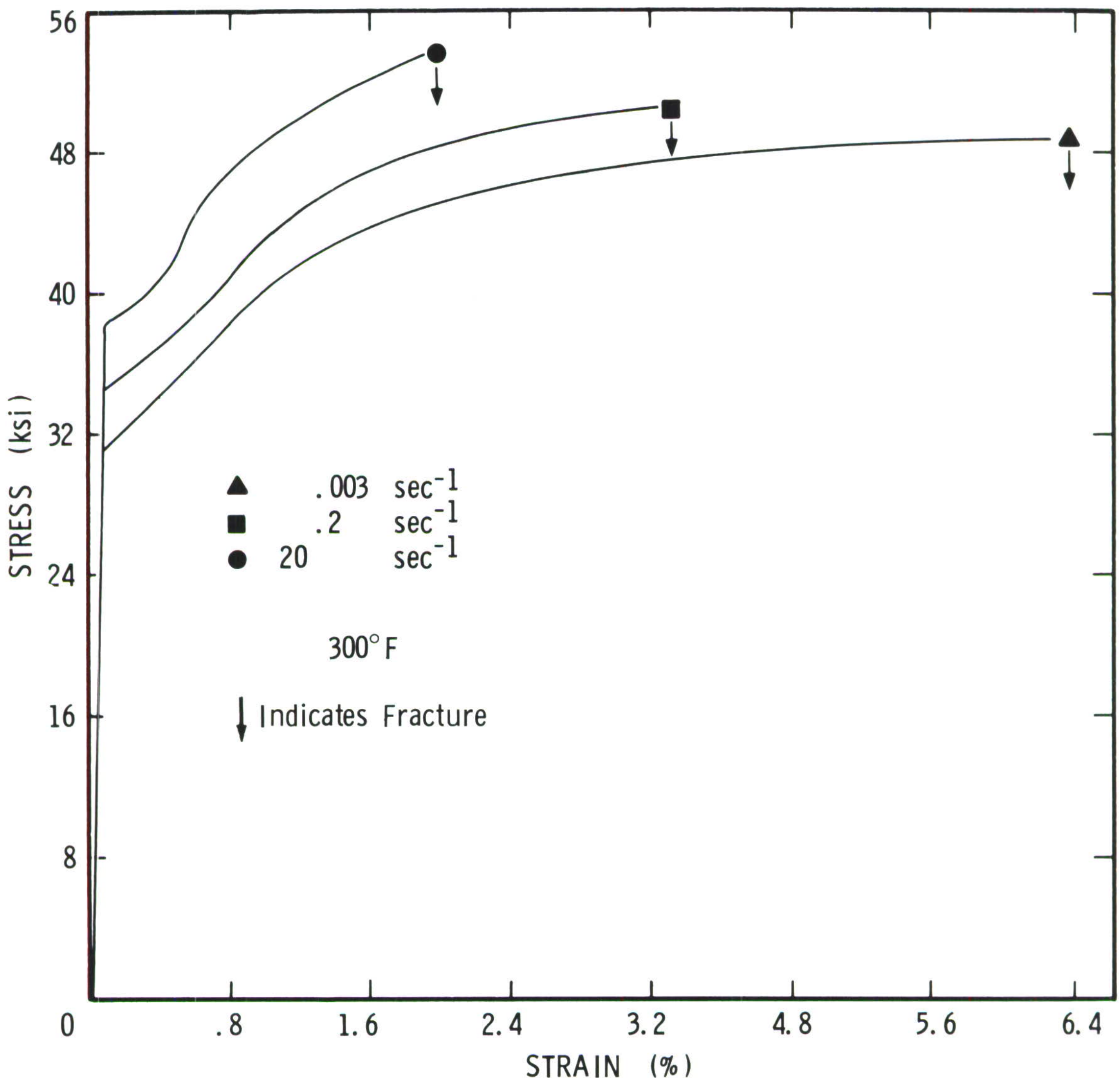

Figure 27 Tension Tests of S-200E Beryllium at 300°F (Block #2)

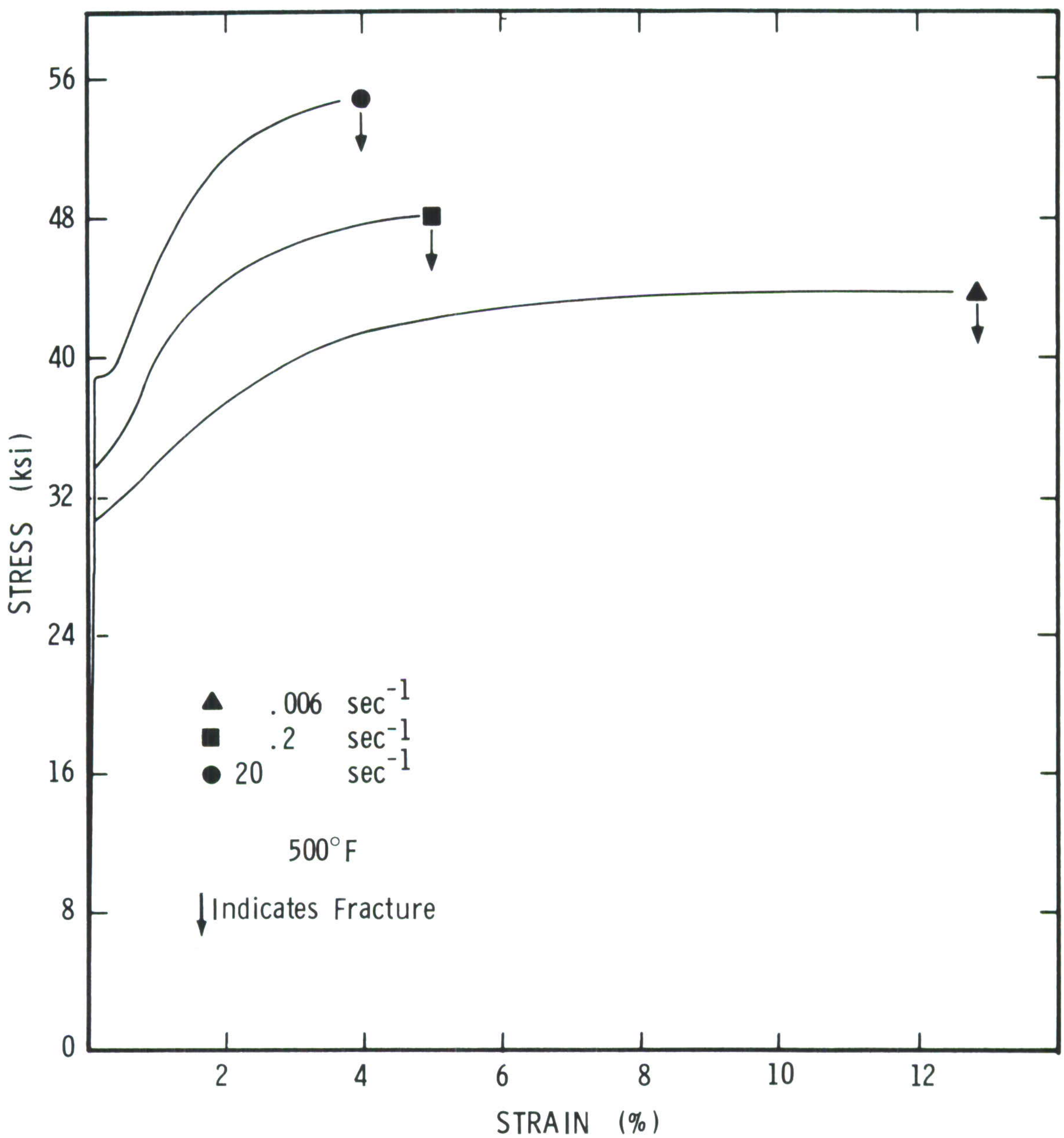

Figure 28 Tension Tests of S-200E Beryllium at 500°F (Block #2)

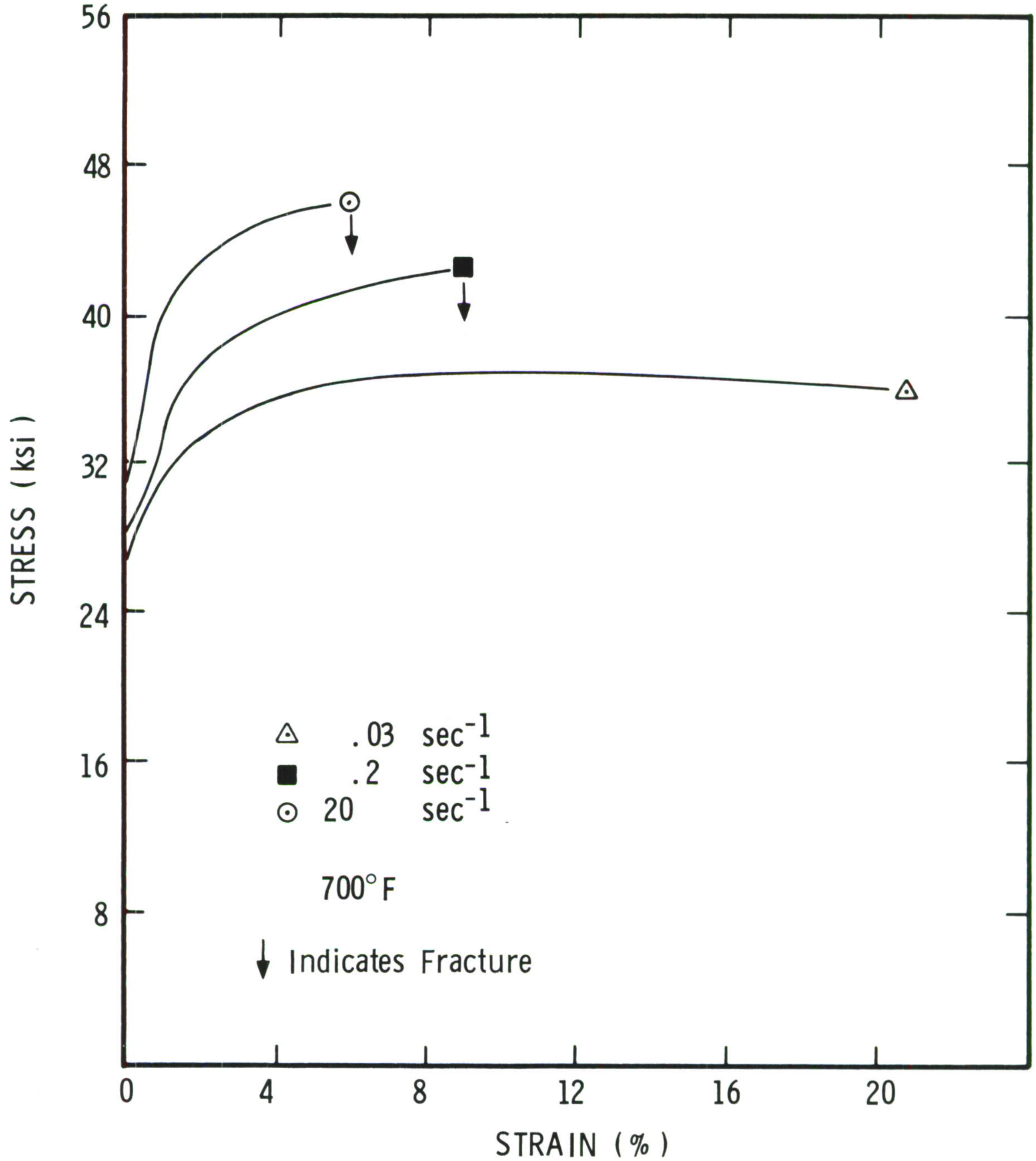

Figure 29 Tension Tests of S-200E Beryllium at 700°F (Block #2)

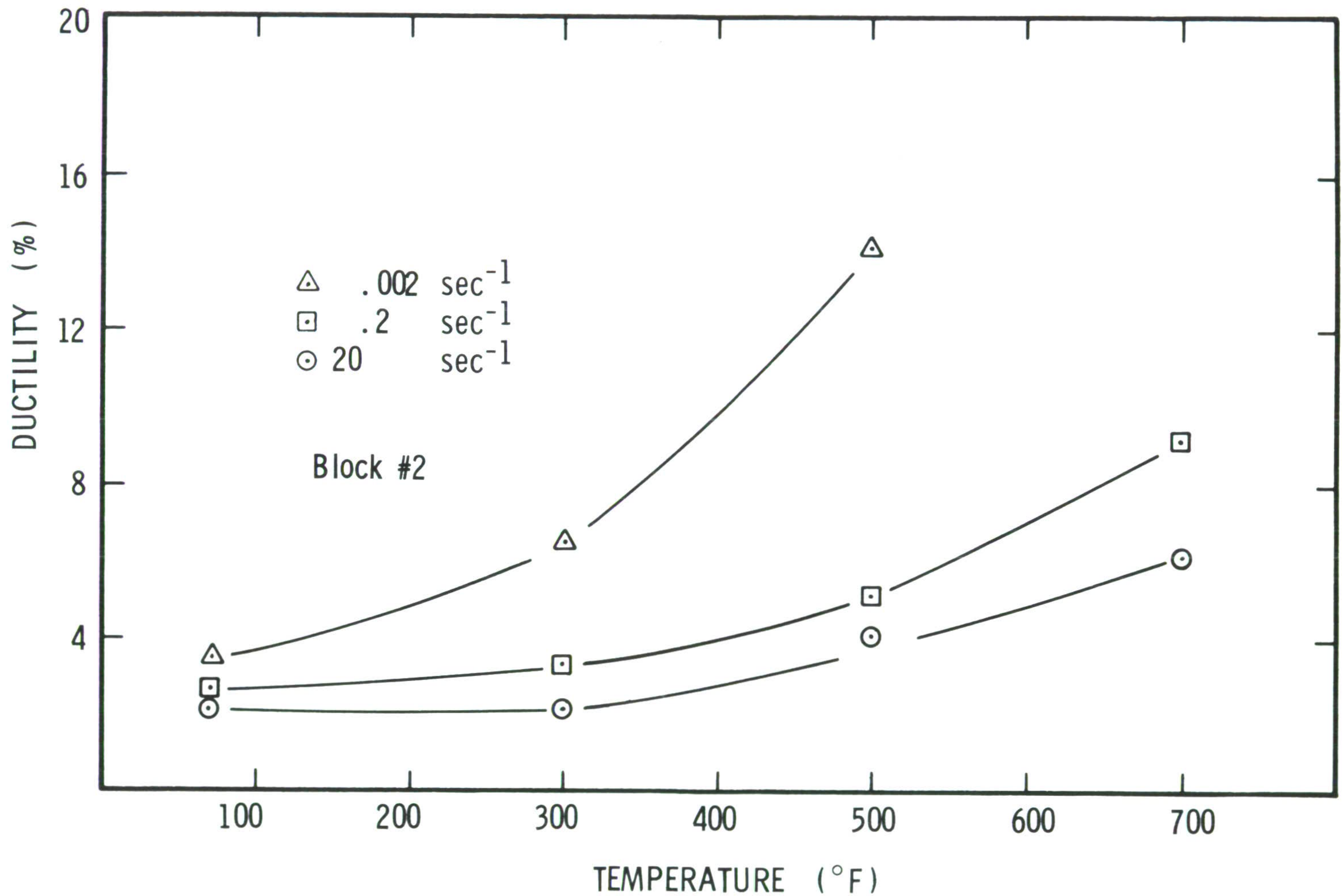

Figure 30 Ductility of S-200E Beryllium (Block #2)

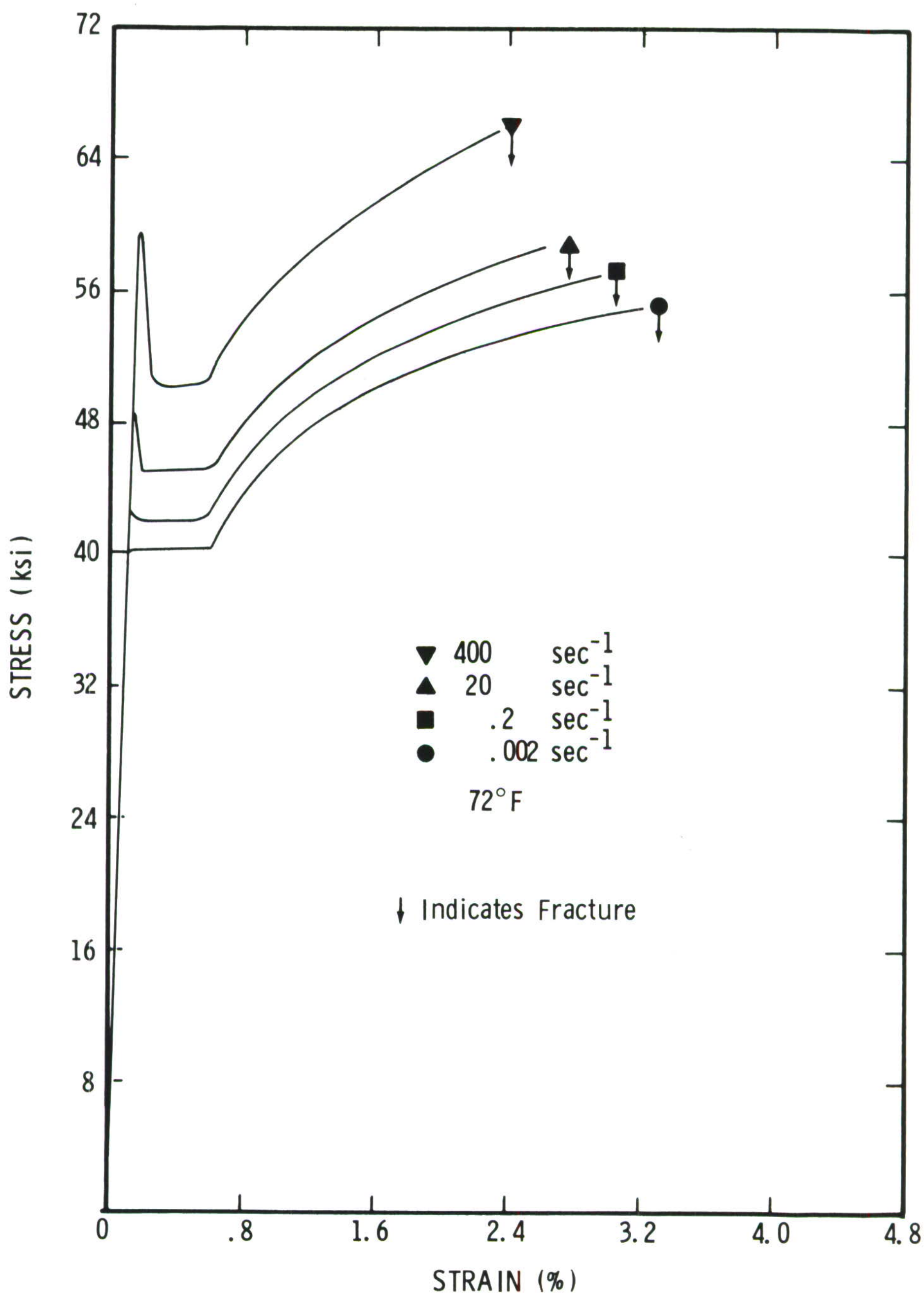

Figure 31 Tension Tests of S-200E Beryllium at 72°F (Block #1)

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13. ABSTRACT

The dynamic mechanical properties were determined for three grades of beryllium: N-50, S-200E and S-200 cross rolled sheet. Results are reported for uniaxial tension stress tests at strain rates between 10^{-3} and 10^{3} sec^{-1} at temperatures from 72 to 700°F. This data and that from a previous report[1] are compared for the effects of three material parameters (beryllium oxide content, grain size, and texture) on the mechanical properties. The change of strain rate sensitivity with changes in these material parameters is discussed.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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High Strain Rate						
Grain Size						
Texture						
High Temperature						

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